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**Cover:** This image, from digitized elevation data for a site in southern Indiana, was generated using Intergraph's Digital Terrain Modeling Software. The terrain model was generated using a triangulation algorithm and then placed into a three-dimensional design file. A false-color composite was then created from one viewpoint of the site. The surface rendering was done with the Gouraud shading technique. For more about computer visualizations as a tool for resource planning, see p. 26.
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Statement of Editorial Intent

The refereed section of URISA Journal strives to share new knowledge in the technical, social, economic, and institutional subject areas that support information systems technology. It is the intent that this section of the Journal contain papers that are representative of URISA’s membership and the broader information systems community. We encourage the participation of system designers, implementors and users as well as the educational and research community.

We hope that the refereed section will provide reliable information and new insights resulting from experience, research and scholarship. We also hope that this section will link academia, industry and the user community through the sharing of critical investigations and organized knowledge. To this end, we are seeking three forms of work: (1) Reports of current research and development pertinent to the overall information systems community; (2) systematic literature reviews of research for the research and development community; and (3) systematic reviews of applications which explain successful systems and procedures to the overall information systems community.

The refereed process consists of a "blind review." After receiving a manuscript from an author, we send it out for review to three or more persons who have been identified as being knowledgeable in the topical area. The name and affiliation of the author are removed from the paper so the reviewers can give it an impartial review; likewise, the names of the reviewers are not revealed to the author. We ask the reviewers to respond to the following: (1) Is the thesis or purpose stated early and clearly; (2) is the significance of the paper stated explicitly; (3) is the thesis argued persuasively; (4) is the writing clear, concise, straightforward, interesting, and in the active voice, where possible; (5) is the paper tied in appropriate ways to relevant literature; (6) is the paper illustrated appropriately; (7) are the methods sound and appropriate to the paper; (8) are the methods explained clearly; and (9) is the paper interesting to many different types of URISA Journal readers?

If the manuscript is accepted and does not need revising, it is sent to the managing editor for comments and final editing. If the manuscript needs revision, assistance is provided by the editors. If the manuscript is not accepted, it is returned with an explanation by the editors. (For complete guidelines regarding the preparation of manuscripts and illustrations, see p. 86.)

Kenneth J. Dueker

REFEREES

In addition to the editors of the journal, the following persons contributed judgement and advice on manuscripts for the first three issues of the URISA Journal.

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The Lineage of Data in Land and Geographic Information Systems (LIS/GIS)

Richard K. Grady

Richard K. Grady received his B.S., cum laude, in resource economics from the University of Massachusetts at Amherst. He began his career as a planner and cartographer with the Commonwealth of Massachusetts. He is currently executive manager for federal systems marketing at Intergraph in Reston, Virginia. He is interested in all aspects of LIS/GIS technology and its implementation, but particularly data quality.

Abstract: The need to integrate data from many sources, often at different scales and projections with different contents and areas of coverage, is typical of building an LIS/GIS database. Source materials tend to be heterogenous. Applications of the data also tend to be heterogenous; and the data are likely to be rescaled, resymbolized, and reprojected to serve some specific purpose. This reprocessing of data often results in an output which feeds another process.

The importance of recording the lineage of data becomes obvious when one considers the machinations mentioned above. To ascertain the validity and suitability of data to support a particular purpose, lineage information is needed by the user. Data producers must be responsive to this need. This paper will review what data lineage is and discuss ways in which it relates to the LIS/GIS community.

The National Committee for Digital Cartographic Data Standards (NCDCDS), in particular, Working Group II on Data Set Quality, defined the lineage of data as follows:

The basis of any quality report is a narrative of the lineage of the data. Lineage includes the original source material and all the processes and transformations leading to the final product (digital database). This information is required for a user to evaluate fitness, and it is required by a producer to maintain and update the data. (1985, p. 115)

As the user of data accepts responsibility for determining fitness for use, the producer must accept responsibility for providing adequate information about data sources, and processing history. The simple statement that “This map complies with National Map Accuracy Standards” (as suggested by U.S. Bureau of Budget in its 1947 document on U.S. National Map Accuracy Standards) no longer suffices; few would argue with this.

The producer of data should clearly label the product with information about its source and processing history; however, it is the user who ultimately must determine its fitness for a particular use. While “truth in labelling” should be demanded, it is too soon in the evolution of LIS/GIS databases to abandon the old axiom: “Let the buyer beware.” In practice, neither producers nor users are blameless. Generally, professional ethics have prevailed on behalf of reasonable practices, but not always. Sometimes there is blind faith in the source of data; other times, there is acceptance or tolerance of error due to expediency.

Inevitably, there will be errors in measurement, processing, and representation of data in an LIS/GIS which result in uncertainty. We are faced with two basic choices for managing this uncertainty. They are: (1) uncertainty reduction, and (2) uncertainty absorption (Bedard 1987).

Techniques for reducing uncertainty include use of standards, testing for accuracy and consistency, and understanding the lineage of data. The absorption of uncertainty has to do with who pays if errors in data cause damages (Bedard 1987).

Clearly, data lineage is not all that a user needs to determine the data’s fitness for a particular use. However, lineage is an important part of reducing the uncertainty associated with using specific data, and it can help a user decide if it is worth absorbing the risk of potential damages. As specified in the proposed
Spatial Data Transfer Specification (which has been submitted to the National Institute of Standards and Technology by U.S. Geological Survey), lineage is one of five sections that should be included in a Data Quality Report (DQR).

Data Quality Report

Traditionally, data producers may have filed a DQR as part of the external documentation associated with a project, perhaps. Some have even provided visual overlays in an attempt to diagram data quality and reliability. More often, it is neglected or not considered essential. The proposed SDTS breaks the DQR into the following sections (USGS 1988):

- Lineage
- Positional Accuracy
- Attribute Accuracy
- Logical Consistence
- Completeness

A description of methods for reporting on each of the above-mentioned sections of a DQR is beyond the scope of this paper. However, the importance of providing and monitoring this information should be recognized; yet, it is often overlooked as part of the operational considerations of an LIS/GIS project. Nyerges (1987) commented on this problem:

Many times databases are not useful beyond the original scope of a project because of the lack of documentation. Data are less useful as information when data describing database production conditions are forgotten and/or misplaced. (p. 320)

Typically it is true that the compilation and management of data for a DQR is of secondary interest to the main purpose of producing and/or exploiting an LIS/GIS database. Anything to make the task easier would improve the likelihood of getting it done. One area of promise is the utilization of on-line metadata.

Metadata, which is simply “data about other data,” can be managed on-line as part of an operational LIS/GIS. Both the U.S. Forest Service and Bureau of Land Management are looking at making metadata a part of their information environments, as well as the U.S. Geological Survey and National Ocean Survey, among others. Once a format is established for the DQR, it can be populated with data as an extension to the database. A data server can store and disseminate the DQR to facilitate evaluation of a dataset’s fitness for a particular purpose.

Data Lineage and the Audit Trail

There are a number of parallels between LIS/GIS and MIS (Management Information Systems). In fact, there has been considerable convergence in some areas. One area that could benefit from more convergence is database auditing. Audits, as well as checking for the absence or presence of lineage information, should become part of the lineage record.

Transactions that change the database occur on a regular basis; this applies to both LIS/GIS and MIS. In a typical MIS environment, once a transaction is approved, it is entered into the database and is also recorded in a transaction history file. This file serves as an audit trail. An audit trail is defined as follows:

. . . the presence of data processing media and procedures which allow a transaction to be traced through all stages of processing, beginning with its appearance on a source document and ending with its transformation into information on a final output document. (Obrien 1979, p. 438)

In business management, the certified public accountant (CPA) lends credibility to financial reports through an audit function. He or she is paid for this service, but remains independent of the firm that is audited. The firm’s transactions are examined, including the collection, classification, and presentation of financial data. This is done based on established professional standards, to verify that the financial reports of the firm adhere to “generally accepted accounting principles.” This function helps to protect the public from misleading financial data. Many investors are fully capable of misleading themselves, without bad data. The same holds true in LIS/GIS, but there is no equivalent, generally speaking, to the CPA.

In staffing an LIS/GIS, the role of the auditor, to attest to data integrity, should not be overlooked. This particularly applies where very large databases and many users are involved. Many corporations with an MIS have a job function defined for a database administrator. This role is similar in some respects to the CPA, except it is internal to the company. If data producers do
not support this function internally, then in some cases the user might provide it (such as a utility company, to verify data from a conversion vendor).

One responsibility of the database administrator should be to define a data dictionary which can apply rules to transactions before any new data are entered into the database, preventing updates that would conflict with existing data. This front-end checking is the traditional means of protecting logical consistency. Another means to check logical consistency is deferred checking, in which the database is scanned after entries are made, checking for compliance with rules as stated in the data dictionary. Although the lineage of the data cannot easily be tested for validity, the above-mentioned techniques should be used for at least checking on the absence or presence of lineage records.

The argument against front-end checking is that it may slow down the data-collection process, which is already the biggest hurdle to timely LIS/GIS implementation. Front-end checking may be a hindrance at times, but it is the best way to assure that data lineage is carried into the digital domain. It is probably too harsh to reject all data that do not have suitable lineage, but such data must at least be flagged.

Deferred checking can supplement input checks. One advantage is that it checks the contents of the database, not the input process. Therefore, it is not a hindrance to data collection. When revision or auditing occurs on an LIS/GIS database, deferred checking can be a means of flagging data that do not have associated lineage information.

These techniques, as basic as they are to MIS environments, have not been widely utilized in LIS/GIS environments, particularly where the lineage of graphic data is concerned. One positive example of long-standing practices of recording chart history is the National Ocean Survey, which is now fully automating these practices. However, more organizations need to institutionalize the use of periodic database surveys and/or continuous administrative processes for checking LIS/GIS databases.

Societal Mandate as Part of Data Lineage

A relatively unexplored area of data lineage is societal mandate. It is the mandate, issued by societal bodies, that enables organizations to build institutions to accomplish goals. As Chrisman (1987) pointed out, many institutions have been created pursuant to various mandates to collect data for some purpose:

The important data collection functions of society are not carried out for technical reasons. The creation of property maps, zoning maps, and all the other municipal functions are not driven by a benefit/cost ratio. Each record is collected and maintained in response to a social need as expressed by the legal and political system. The search should not be for the flow of data, but for the mandates that cause the flow. (p. 1369)

This is an important point for users of LIS/GIS technology. The producer of data should include as part of its lineage the mandate, (or enabling legislation, where appropriate), that led to the collection effort. This information would be very useful to the user of such data in determining its fitness for use.

Cartography and Data Lineage

Anyone who is properly trained in cartography is fastidious about source materials. Decisions must be made about map contents, based on answers to the following questions:

- What is the name and nature of the authority responsible for the source materials?
- How familiar is the authority with the area of coverage?
- What is the date of the source, how and when was it originally compiled, and has it been revised?
- Was it derived from another source and, if so, is that source larger-scale?
- For what purpose was the data collected?
- What is the accuracy?
- What generalization and/or transformation procedures were used, if any?

These questions are representative of what must be determined by the cartographer who collects data. Over the past 25 years, there has been a proliferation of special-purpose mapping by non-cartographers. In part, this proliferation has been due to the advent of automated LIS/GIS technology, where a map is often just an output to show the results of a particular analysis. Such maps are often used themselves as input to another analytical process. When this is done without regard to the
fitness of the data, error propagation is highly probable.

Applications of LIS/GIS technology have increased the need for multi-discipline expertise. Cartography is fast becoming a set of communication tools and skills adopted by several disciplines outside of traditional map-making. While they are adopting some of the tools and skills, they are not necessarily adopting the principles.

One of the most basic cartographic principles is: “Thou shalt not derive a large-scale map from small-scale source materials.” As we have moved into the digital domain, with many non-cartographers making maps to represent the results of spatial analysis in LIS/GIS, there is often blindness and/or ignorance related to this simple principle.

Clearly, the need for someone to make decisions about sources, content, and design of digital databases has intensified with the increased adoption of LIS/GIS technology. This role does not have to be played by a cartographer, but certainly by someone with the professional discipline to be fastidious about data lineage.

The Spatial Reference Component of Data Lineage

Most of the discussion so far has revolved around source materials as a component of data lineage. The other major component relates to “the processes and transformations that lead to the final product (digital database).” The processing history becomes particularly relevant with the transition from manual to automated LIS/GIS technology.

In the proposed Spatial Data Transfer Specifications (SDTS), spatial reference is divided into three modules:

(1) Internal Spatial Reference
(2) External Spatial Reference
(3) Spatial Domain

The internal spatial reference module describes the translation and scaling parameters necessary to transform the internal coordinate system of the data into an external coordinate system. The external spatial reference module defines the geographic coordinate coding (spatial address) of objects, tied into a geodetic reference system. The spatial domain module specifies the geographic area of coverage by defining a series of spatial addresses that delineate the area (USGS 1988).

It is essential to tie spatial reference into ground control to make the coordinate system explicit. Many have called for better documentation of ground control, and for survey monuments to be included in digital coverage whenever possible. Not only does this allow for accuracy to be tested, but it allows for data from different sources to be registered in combination. Merging coverages is a common requirement, and problem, in LIS/GIS environments.

There is an ongoing debate over the application of geographic coding schemes that use coordinate locations alone to distinguish points. The problem arises when a given point has different coordinate locations on separate source materials. One approach to this problem is to distinguish between measuring a point’s location and naming it as a place. Dutton (1984) observed the following:

If survey monuments and other significant locations had systematically constructed geocodes [names], the problem of registering coverages would become that of identifying their common control points by name-matching, then fitting a transformation to common coordinates. (p. 278)

The spatial reference component of data lineage, including well-documented ground control and other significant point locations, can help ascertain data quality and reduce uncertainty.

The Temporal Aspect of Data Lineage

When it comes to data lineage, several “dates” are of obvious importance. These include: the compilation date of source materials; the publication date of source materials; the dates of original survey; and the date of revisions. Of course, all of these dates relate to single points in time. And yet, the phenomenon we try to model in an LIS/GIS is not static; it changes, continually.

The data structures being used today, which were designed to represent static phenomena, have limitations for modeling the time continuum. Chrisman and Langran (1988) have proposed a framework for handling temporal data, to facilitate queries such as:

- What was the previous state, or version, of this object?
- What has changed (during a period, or at a place)?
• What is the periodicity of change?
• What trends are evident?

Until the time dimension can be represented structurally, LIS/GIS can be used to store temporal attributes for each feature, thereby allowing some limited analysis based on change over time (Chrisman and Langran 1988).

There is great interest in change detection for many applications of LIS/GIS technology. One particularly useful technique is overlaying two images of the same area, taken at different times. This snapshot technique can be used to observe change, delineate it, and update vector map data. Obviously, the date associated with images and vector maps becomes very relevant to applying this technique. It is just one reason why the temporal aspect of data lineage is so important.

Summary

This paper has attempted to help build an understanding of what lineage is comprised of, discuss some techniques for incorporating lineage into LIS/GIS, and raise some concerns about the risks of not having it. The inclusion of data lineage in LIS/GIS requires a conscious effort and application of sound procedures and principles. The lineage of data, including source materials and processing history, is an important part of the Data Quality Report (DQR) as defined in the proposed Spatial Data Transfer Specification (SDTS). Data producers must be fastidious about including lineage information, and it can be stored and disseminated as metadata—data about data. Users of data must be careful in determining the data's fitness for a particular purpose, and aware of the risk they absorb when they apply data without knowing their lineage. An important part of lineage is "when" data were acquired; but also important is "why" it was created to begin with.

References


A Policy for Technology Leadership
Richard de Neufville and Jennifer Croissant

Abstract: The field of GIS as we know it is threatened even as it begins to enjoy its greatest success. We are faced with the possible "death of cartography." It is increasingly possible that, in terms of dollar volume, the greatest practical use of topological databases by managers and decision-makers will by-pass graphical displays and rely on more cost-effective means of conveying spatial information.

This article presents this issue by exploring the nature of leadership and technological innovation, with a focus on the way a professional paradigm defines and limits a field. A case study of the development of GIS illustrates these concepts. Current technological and commercial trends are then outlined suggesting that the nature of GIS may change radically by the year 2000. The problem is whether our institutions can overcome their inherent resistance to change, and respond in sync with the speed of technical progress. The question is: What should URISA and GIS practitioners do to be technological leaders in the future?

GIS (geographic information system) is now really getting established. All of us who have been part of the field for the last 20 years can recognize this success. What used to be difficult, technically and organizationally, is increasingly easy and routine. The indicators are certainly positive: the money spent on GIS has been booming, employment opportunities are up, and quality professional journals such as URISA Journal are being published. We can justifiably feel that our emphasis on computer mapping has been vindicated.

Yet there may be trouble ahead. We may be facing a serious, fundamental challenge to the concept of what a GIS is and what it should do. The exploding demand for digital cartographic data is increasingly being fueled by business—by managers who have little or no interest in maps per se. These customers want decision-support systems (DSS) that provide useful information fast and cheaply.

For many decision-makers, maps are an inferior way to present geographic information. It may be far more efficient to tell someone where the nearest service is, or how to get somewhere, by using a text printout or a computerized voice message (such as used by telephone information services in the United States). These alternatives to maps may be much more cost-effective: They reduce costs by eliminating the need for the more expensive graphic terminals and for cartographically trained personnel, and they increase productivity by reducing the response time of the operators of the system.

Consider the following examples of the many significant uses of topological databases that by-pass the use of any map display:

- Major express services (such as Federal Express and UPS) are contemplating national roll-outs of services that allow their operators to tell customers where the nearest drop-box facility is. This
is done via a text message on a screen.

- Major mailing services (such as Donnelly, Metromail and R.L. Polk) not only routinely use geographic data processing in customizing their services, but in fact are investing millions of dollars in digitizing improvements to the TIGER files. Yet their operations may never see a map in practice.

- Several of the “Baby Bell” regional telephone companies are preparing improved information services that would answer questions such as, where is the nearest drug store that is open now, in which the operators would never see a text, much less a map.

Computer processing of geographic data may signal the “death of cartography.” The map as a vehicle for encoding and transmitting information may go the way of the watch dial and hands. Admiringly developed for its time and technology, the analog watch is now more decorative than efficient. Digital watches tell time more simply and directly.

In the words of the National Research Council’s 1990 Report on Spatial Data Needs:

The field of digital geographic data processing . . . has grown dramatically, not only in terms of the numbers of individuals involved and the variety of applications addressed, but also in terms of the sophistication of the applications . . . It is discovering new capabilities it never realized it possessed and exploring them with both awkwardness and self-confidence . . . Perhaps more importantly, the field is now developing a certain self-awareness, a realization that it has a future and one that can and must be directed. (p. 17)

This article is an attempt to stimulate a healthy discussion of the future of GIS. The argument consists of four major sections. First, it discusses the basic concepts of leadership and innovation, with particular reference to the important notion of the professional paradigm. It next suggests that real innovation inevitably clashes with established, successful concepts, and displaces them if the paradigm does not respond quickly. It then illustrates these ideas by a case study of the evolution of traditional cartography and mapping into geographic information systems. It concludes with suggestions of what may be necessary if we wish to maintain technological leadership in our chosen field.

Leadership, Innovation and Paradigms

Leadership

Leadership, at its core, involves two tasks:

1) Creating a vision of how things might be different, of a goal to be achieved; and
2) Motivating and bringing people to that end.

Much more is also required, of course, as Gardner (1987, 1990) and others point out, but these are the essential elements: the idea for change and its implementation.

Leadership comes in two flavors, differentiated by the degree of change. Using the phrases popularized by Burns (1978), one usually speaks of either transactional or transformational leadership. The former is the kind of direction normally provided by good managers carrying out their business as usual: They establish goals, such as higher sales or better products, and mobilize their staff to achieve them.

Transformational leadership is more interesting and challenging. It seeks to establish new pathways, new modes of operation; it tries to transform the very nature of the organization, to bring people to achieve quite different goals, by unusual means. Henry Ford, for example, may be considered a transformational leader in that he revolutionized the concept of manufacturing and distributing automobiles. Transformational leadership is truly innovative.

Innovation

Technological innovation is, in many ways, the result of leadership. It is the change achieved by deliberate thought and acts. Like leadership, it comes in two versions: incremental and radical.

Incremental change is the gradual refinement or evolution of a technology. For example, the steady improvements in propeller-driven aircraft between the World Wars represented incremental change. So does the continual development of the DIME files over the last decades. This process results from the steady focus of proven technical skills on a problem, from transactional leadership of the research and development process.
Radical change embodies some kind of technological leap. The switch from internal combustion engines to turbojets for aircraft is an example, as Constant (1973, 1980) describes in detail. So is the shift from manual to computer-driven production of maps. Radical technological change requires transformational leadership; it requires a fundamental redirection of established practice.

Paradigms

Following Kuhn (1962, 1970, 1977), we can recognize that any technological discipline is normally organized around an establishment that defines the standard direction of research or modes of design. This complex of established practice is known as a paradigm.

A technological paradigm is the community of professionals and institutions in a field. It is both the people and their extensions: the technical journals, the societies, the graduate programs, etc. As any community, it is a source of many strengths to its members.

The paradigm first of all defines who is a member of the field. A geographer, for instance, is not simply someone who practices what the dictionary might label as geography; professionally a geographer is a person who does what other geographers are pleased to label as such, and is likely to have gone through a specialized education in the field. By defining who is an insider, the paradigm specifies who is eligible for its support. In addition to the encouragement and promotion of one's efforts that comes from a group of like-minded colleagues, this support typically translates into significant material benefits: fellowships for students, jobs reserved for graduates, government grants directed to the profession. For example, when the U.S. National Science Foundation endowed a National Center for Geographic Information Analysis (NCGIA), it was inconceivable that this not be placed in a department of geography, even though much of the best work nationally on database management and information analysis is done in computer science and management departments.

The paradigm also defines what is legitimately part of the field. It does this by its norms for training programs, rules for joining professional associations, and editorial practices for its journals. These norms are often quite stringent and may even have the force of law. In the United States, for example, one may generally not even take the bar examinations if one has not been to law school. Likewise, many countries and states have legal restrictions on who is eligible to become a land surveyor. These standards are helpful to a community because they establish a degree of competence and provide legitimacy—and also of course because they limit the supply of specialists and thus enhance their rewards! The drawback is that these rules discourage change, even at the margin. An established community naturally tends to consider change "inappropriate" in that it may redistribute power and status. At MIT, for instance, the faculty constantly worries whether even minor curricular innovations (such as subjects in computer science) would be acceptable to the Accreditation Board for Engineering and Technology (ABET).

A paradigm, finally, defines how a profession is to be carried out. Through its education and by example, it defines the criteria for good work. These are useful because they expedite normal practice. Established methods, such as double-blind testing in the drug industry, have proven their efficiency. Clear criteria of performance focus researchers and designers on specific goals and facilitate the comparison of alternatives. In map-making, for example, a principal criterion of quality has been topographic accuracy. For cartographers a key question is: does the map give a precise bird's-eye view of the territory? Do the streets and rivers bend exactly as they should? This focus has certainly led to topographic maps of exquisite accuracy and detail. The drawback has been that this criterion proved to be a major reason for resisting the introduction of computers in mapping.

Paradigms versus Innovation

An established paradigm is the natural enemy of fundamental innovation. Radical technological change, which by definition brings in some kind of reorientation of a field, as the assembly line did in automobile manufacturing and the jet engine did in the aviation industry, forces a shift in the established paradigm. Such shifts are most uncomfortable: Previously
valued skills lose importance and their practitioners are set aside in favor of new people with newly suitable skills; established institutions and companies are displaced by up-and-coming, upstart groups. Paradigms will resist fundamental innovation; the more successful the paradigm, the deeper the resistance will be.

Paradigms confront radical innovation in each of the important dimensions of who is legitimately involved, what is the nature of the task, and how the results are to be evaluated. Real technological change will thus be broadly challenged, and must expect a long struggle for acceptance.

Who

The real innovators are typically outsiders, mavericks in some sense. (See the case studies of Doig and Hargrove, 1988, for example.) This is not accidental. The insiders, the persons socialized in the methods and virtues of a paradigm, do not easily see beyond its limits. These experts are so well indoctrinated in their specialty that they have lost their ability to question it fundamentally; they have what is known as a “trained incapacity” for innovation. Each of us probably has some personal experience with this phenomenon. Outsiders, on the other hand, have not learned what “isn’t done” or “isn’t part of the discipline.” They do not have a personal stake in the established processes, and are thus freer to challenge, to experiment, and to innovate.

Right from the start, the paradigm closes its eyes and ears to radical changes enunciated by the innovators. First of all, a mental block goes up. These outsiders, the reasoning goes, cannot understand the real issues because they are outside the field. Furthermore, as outsiders, they effectively have little chance for access to publishing in the journals or to using the other professional platforms of the field. The openness of a field to presentations based on some objective measure of quality is quite theoretical in practice. After some 30 years of successful professional experience, I know very well that the acceptance of research grants, articles and requests for podium time depends upon friendships and position within the professional hierarchy. The paradigm automatically tends to exclude the outsiders and the messengers of fundamental innovation.

The case of Admiral Hyman Rickover, now acknowledged as the father of the U.S. Navy’s nuclear fleet, makes the point (Doig and Hargrove, 1988). He was socially and professionally an outsider because of his background and career as an engineering officer. The mainline U.S. Navy repeatedly tried to fire him as he developed nuclear reactors and radically transformed the Navy’s fleet. Technical quality of itself was no guarantee of acceptance.

What

A paradigm by its nature has defined the focus of a field. These definitions often close it off from new concepts. An established discipline normally suffers from “hardening of the cate-
gories,” an institutional form of trained incapacity.

Consider the way the field of cartography thinks of a map as a two-dimensional representation of topographic data, and focuses its attention on this artifact. In so doing, cartography has been very successful: A modern map using conventional, well-recognized symbols can portray up to 70 different categories of data clearly and distinctly.

Yet we must remember that maps are not ends in themselves—only decorators want them on that basis. Maps are strictly intermediate devices; however sophisticated, they are merely a means for conveying geographic information to users. There are many other ways of doing this, however. For example, think of how you tell a friend over the telephone how to get to your house, or consider how Hertz gives directions to common destinations around its car rental agencies by printing out a sequence of instructions. But the discipline of cartography, polarized around the charts it has developed into modern maps, gives short shrift to means of presenting geographic data that do not involve maps. Think of the last URISA conference you attended: What booths featured displays that did not involve maps? Despite what may be written in some of the forward-looking literature, our paradigm in practice virtually excludes innovations in GIS that are not map-oriented.

How

A paradigm also implicitly defines the criteria for evaluating
technology. These reinforce the standards of what is the proper focus of a field, and serve as the technical reasons for rejecting real innovations.

The standard criteria for materials for body panels in the automobile industry, for example, have been those associated with the traditional choices: varieties of steel. The criteria thus reflect strength, resistance to buckling and several physical properties of the material itself; they do not consider other important qualities such as safety or ease of manufacturing. The traditional criteria have been biased against extruded plastics, materials which can be molded into one part to substitute for several steel parts and thus reduce the cost of fabrication. If the automobile industry stays with the traditional criteria, it denies the advantages of really innovative materials, and effectively resists their adoption.

Consider cartography again. One of its prime criteria for excellence in GIS is associated with the traditional map—specifically, complete accuracy of the representation. Contrarily, practical cartography is hardly concerned at all with speed or ease of including corrections (maps of major cities are frequently several years behind in terms of new streets, subway stops, etc.). Yet practical decision-support systems are typically most interested in speed of response, the key determinant of the labor content and thus the cost of operating any customer-inquiry system, and the key advantage of computers. Contrarily, they are less interested in bird's-eye accuracy (when directing a friend to "go straight down the expressway," it is of no importance if the road actually wiggles back and forth). By using detailed accuracy as a criterion for producing maps, cartography effectively delayed the implementation of widespread computerized mapping, possibly by decades. Map publishers such as Rand McNally still produce their maps in the traditional way, and still do not know how to bring their maps up to date rapidly.

Consequence

The paradigm of any established technology is inherently antithetical to radical innovations, to fundamental shifts in the paradigm. The establishment will ignore radical innovators at best, cast them out and repel them otherwise. It will denigrate their ideas as inappropriate, and evaluate them by criteria ill-suited to the special advantages of the really new technology.

The irony is that, as an innovative technology gets established, it becomes less receptive to fundamental change. This presents no problem if no radical technological change is likely to emerge in the field. But this phenomenon presents an absolutely basic problem if the field is indeed about to undergo basic change. The profession must then either learn how to readjust, or face the real possibility of being displaced.

Evolution of GIS as a Case Study

The history of the introduction of computers into the mapping process illustrates the broad opposition of established paradigms to fundamental innovation. We ought to learn from the experience, so we are not condemned to repeat it.

The idea of the computerized map is now well established, even if it is still very far from being universally used. Yet this has taken over a generation of effort. Why is this? Drawing maps is a tedious, repetitive process. Conceptually, it would seem ideally suited to automation. In fact, the cartographic paradigm has resisted the transition tenaciously.

The details of the "analogue to digital revolution" in mapping are documented in the Special Issue of the American Cartographer devoted to the subject (Chrisman; Copsock; Dangermond and Smith; Goodchild; Petchenik; Rhind; Tomlinson; 1988). Carter (1984) explains the technical concepts of computer mapping. Since GIS shares with cartography the idea that a map is the central product, the following focuses on the who and how issues of the development.

Who

Map-makers have traditionally been professional cartographers working with skilled draftsmen and engravers. Major producers of maps, such as Rand McNally, maintain large, long-term teams of these craftsmen.

The persons who wanted to bring computers into map-making did not belong to this tradition of cartographic production. They were pretty much computer programmers in practice, whatever their formal back-
ground. In the early 1960s when the move toward computer-mapping began, nothing much happened if you did not spend a lot of time with the machine. Major foci of activity, such as the Harvard Laboratory for Computer Graphics and Spatial Analysis, located in the architecture department, did not reference themselves to maps either by name or discipline. The innovators were clearly outsiders. And as outsiders they were not really welcomed into the cartographic paradigm, which, of course, is one of the reasons for the founding of URISA and why we still feel today the necessity for creating our own journal.

How

The essence of what is done in cartography is, naturally, the production of accurate maps with many layers of detailed data. Once produced, the maps are relatively static: They are printed in some physical form and updated infrequently. This objective is quite distinct from the needs most easily served by computers.

The computer and its peripherals are best at correcting and reconfiguring data. Conversely, a computer system has difficulty with precise drawings because exquisitely detailed resolution severely increases the need for computer memory, slows down production as data retrieval becomes more difficult, and pushes the capability of printers to their limits. Computers, whatever their advantages, could not originally do the job as defined by the specifications of the traditional paradigm.

It is little wonder that the early enthusiasts for computer mapping met with incredulity, "facing . . . distinctly unsympathetic and disbelieving audiences" (Rhind 1988).

The criteria for evaluating maps, in conformity with the standards of cartography, were stacked against computer-based products. They weighed precision highly and flexibility hardly at all. A system which generated stick drawings (using vectors) or coarse curves (due to the pixels) was of virtually no interest, however rapid and flexible it might be. Under these circumstances, computer maps could not have much of a future with the traditional paradigm.

Computer maps have indeed been slow to enter practice. Only now, in the early 1990s after a generation of effort, does success seem to be in sight as the estimated market for GIS products climbs above $100 million a year (or more, depending on what precisely one counts in the total).

A New Paradigm

To achieve success, the computer-mappers have had to create their own GIS paradigm. They have done so around the users who particularly require up-to-date geographic data and value the flexibility and speed of computer systems, and who are not especially concerned with the beauty of the graphics. These participants in the paradigm include utilities, companies or towns that need to track the constant changes in their environment: new equipment, market districts or land use.

The GIS paradigm is well on its way to becoming firmly established. It has its societies, such as URISA, its journals and trade magazines, its academic programs and even its own National Science Foundation program, the NCGIA. At present it is still young and flexible, however, and can be responsive to fundamental technical change.

In establishing the new GIS paradigm, the innovators have not really converted the Olc. So far, indeed, they have barely affected it. An anecdote makes the point. Of the 53 geography departments placing explicit course announcements in the 1987 edition of Peterson's Annual Guides to American education, only two (!) cited geographic information systems, two more "computer and traditional mapping," and one more mentioned its "excellent computer facilities." That is, in only 10 percent of the salient academic departments had computers caught on by 1987! This is a full 30 years after I was introduced to the computerized COGO (coordinate geometry) systems as an undergraduate in engineering. Clearly there has been more than a minimal resistance to the technological innovation.

The Next Fundamental Innovation?

The boom in GIS and its prospective adoption for Spatial Decision Support Systems (SDSS) as a standard business tool (Bylinsky, 1989) is certainly most encouraging to all of us in the
field. But as we think about how this is happening, there is an irony: Just as we are “winning,” we may be “losing.” The businesses and operations managers who are fueling the boom have a different view of how geographical databases should be used, and may be leading us to a fundamental reconceptualization of GIS to SDSS. Indeed, a GIS and a SDSS are not necessarily the same at all (Densham and Goodchild 1989; Goodchild 1989). We may be contemplating what some observers call the “death of cartography.”

We must expect that the “Golden Rule” will operate as generally for GIS as it does elsewhere: “He who has the Gold, makes the Rules.” The future of GIS will depend on what the big users want from it.

First, who might these users be? According to the National Research Council’s recent report:

As one business executive put it recently: “By the end of the coming decade, a large proportion of travel and transport will be regulated, guided, or assisted by derivatives of the TIGER database.” (National Research Council, 1990, p. 26)

Indeed, all those interested in transportation, in dispatching deliveries and pickups, organizing service calls, directing customers to stores, and so on may be interested in using SDSS for management of their logistics. Indeed, we are already seeing companies such as Federal Express and UPS, Fortune 500 companies operating their fleets, taxi cab management companies, and referral services beginning to use GIS on a significant scale (de Neufville and Vignos 1990).

Note that this community of users is made up of outsiders to the current world of GIS. They have not been trained in geography or land use; they are more likely to be managers or engineers. They do not share the same expectations or norms.

Will these users really influence the nature of GIS? The answer must definitely be yes. A mere 1 percent of their current expenses is a market of several hundred million dollars; they will certainly have a major impact. And they already are major players: Months before the TIGER files were fully released, large private corporations were investing millions of dollars to extend its geographical database for logistical and other commercial purposes. Based on current discussions, we may also expect that in a few years some private companies—acting either alone or as a consortium—will build a DIME-like file (i.e., with address ranges) from TIGER.

How might these users influence GIS? The key observation is that transportation managers want decision support systems (SDSS), want solutions to their daily problems, and have no intrinsic reason to be interested in maps which, after all, only offer limited ways to present data. A map can locate a vehicle on a map, but would be hard put to indicate its status, tell us whether it is full and indicate if it has many more stops on its route, etc. A map can locate a business, but cannot simultaneously display its record of transactions, credit rating, current orders, etc. A map fails precisely in those domains that concern a logistics manager.

Managers of transportation systems can be expected to want to use their SDSS and geographical databases the same way as their other databases. They are used to rapid responses, reports in straightforward language, and the ability to execute structured queries. They cannot be expected to wait for slower displays that use specialized symbols. Their criteria of performance for an SPSS are quite different from those for GIS.

A typical SDSS adapted to operational managers produces text listings when responding to a query on the “cartographic” data. In one application, an operator in a central office handling requests for regional deliveries of pizza will (a) get a listing of franchises near the caller, (b) see if the nearest can currently meet the request, (c) identify the delivery route, and (d) check the caller’s credit rating (Ferraris 1987; Wong 1987). Similarly, the GeoSpreadSheet prints out data associated with zones, adjusting instantaneously to a manager’s “what if” questions about the boundaries of sales or delivery districts (Cocke 1989). The map in such systems is quite secondary, if it exists at all.

These new SDSSs contrast markedly with the prototypical current GIS, such as ARC/INFO, to take a prime example. Even in its PC version, this kind of standard GIS requires highly trained operators, responds slowly, and meshes with difficulty with other business databases. It is now used by businesses (see Bylinsky
1989), but is this map-oriented format the one that will be most suitable in the years ahead?

Consequence

It is entirely possible that the world of GIS will undergo radical innovation in the years ahead. The new SDSS paradigm would feature:

- **Who**: Different kinds of professionals, that is, managers of businesses in contrast to planners for government agencies.
- **What**: A new range of products, notable for the absence of maps and other traditional kinds of graphical displays.
- **How**: Emphasis on speed, legibility and flexibility in contrast to the cartographic standards.

The question for those of us that constitute the GIS paradigm today is whether we can adjust to accept this innovation in geographic data processing? Or whether we will disregard it, exclude it, and fight it? Will we react as the traditional cartographers did to computer mapping? Or will we learn from that experience?

A Policy for Technological Leadership

Those of us interested in establishing and maintaining technological leadership must look for ways to facilitate the process of fundamental innovation. A key difficulty is that such radical change typically faces a long, difficult struggle against established professional groups. Paradigms do not want to be shifted. What is to be done? How can we do it?

The central policy recommendation seems obvious: If the core resistance to real change is that existing paradigms impose perspectives and discourage new visions, the solution is to facilitate the development of the new views. What might this mean, specifically?

Who

The essence of a paradigm is a community of like-minded professionals. Facilitating a new paradigm means creating a cohesive group tied by common interests in the same issues. When an innovation concerns new products, a good way to start a community is by setting up users' or special interest groups (SIGs). These will inevitably form if the new SDSS vision of GIS ever comes about. The real issue is whether the existing GIS community will encourage them. I would recommend that we make a special effort in the direction of the new SDSS users, and actively seek to include them in the fold.

What

A community of practitioners is not an end in itself. It is a means to develop consensus about the nature of the innovation. Judging from the literature, the conference sessions and discussions with colleagues, I see very little awareness of SDSS and of the non-standard ways geographic databases are being used in industry. The GIS paradigm is already becoming set in its ways, and is already adopting the pattern of excluding non-standard views. If the presentation does not fit the mainstream, send it to a different journal, conference or whatever.

The second recommendation follows on the first. The GIS community, its journals and its conferences ought to make a determined effort to be on top of all the developments in the use of SDSS. I am sure we are not at present, because there are big gaps in the literature. If the existing GIS community fails in this task, it risks being overtaken as the new uses gain prominence. The March 1990 NCGIA workshop on SDSS research was certainly an excellent step in this direction. Such efforts must continue.

How

A community of practitioners is also a means to develop consensus about the standards for evaluating an innovation. In arguments about whether a radical innovation is worthwhile, it is crucial that the innovation be judged by criteria which recognize its special advantages. As everyone in the software industry knows, the development of criteria by which products are evaluated are key to acceptance.

The final policy recommendation is that the GIS community should participate in developing explicit standards of performance for SDSS, and for the new, map-less forms of using geographic databases. If we do so, we can also incorporate our own concerns. If we do not, we risk the development of criteria by the new community of producers and users, which will
work to our long-term disadvantage.

Conclusion

If we want to maintain technological leadership we must act like leaders. We must not just keep abreast of developments, we must be at their forefront. This may be painful when dealing with radical change. The GIS community certainly cannot expect to be comfortable with an innovation billed as the “death of cartography.” But it would seem that if we do not take this development seriously, and position ourselves to shape its future, we risk being eclipsed. So we urge our colleagues and the leaders of the GIS community to participate aggressively in the exploration of the new uses of Spatial Decision Support Systems.

Acknowledgements

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References

Temporal GIS Design Tradeoffs
Gail Langran

Gail Langran is a senior systems consultant with Intergraph Corporation's Federal Systems Division. She presently is involved with the design of an automated nautical charting system for the National Ocean Service, which includes a temporal database to track nautical feature data.

Abstract: A fundamental problem when designing a temporal GIS is how to structure multidimensional data efficiently. This discussion considers the characteristics of different types of GIS data and applications, then introduces the concept of dimensional dominance and its use in guiding data-structuring decisions. Knowing how data are to be manipulated by an application is essential when determining how to organize them in storage and memory.

A reasonable future goal for GIS is to represent and analyze changes in spatial information over time. A temporal GIS would store historical geographic states; provide methods for detecting trends, cycles, or other patterns in the spatiotemporal data; and assist in explaining spatial processes or forecasting future states. In brief, the prospective functions of a temporal GIS are inventory, analysis, updates, quality control, scheduling, animation, and static mapping (Table 1).

While temporal capabilities would enhance a GIS considerably, designing such a system is a challenge. Massive volumes of data will threaten the usability and usefulness of a temporal GIS unless algorithms and data are carefully structured. This discussion examines the concept of dimensional dominance (Langran 1988), where time or space is of primary concern to a user, as a means of guiding data organization. Remarks are aimed at those with an interest in GIS database design. The sections that follow examine the temporal needs of various spatial applications, discuss how data can be organized in storage for maximum responsiveness, and consider the likelihood of a monolithic temporal GIS design.

Earlier work leading to a temporal GIS has addressed a range of conceptual and practical topics. Published works have introduced a conceptual model for spatiotemporal information, addressed other conceptual issues, compared potential spatiotemporal data structures, examined temporal database alternatives, and described practical methods of representing geometric changes to geographic data (Langran and Chrisman 1988; Armstrong 1988, Langran 1989a, Langran 1989b, and Langran 1990).

Ideally, a single monolithic system design would meet all temporal GIS requirements. But in reality, data are clustered in storage based on their innate characteristics and on expected access patterns. Because spatiotemporal data and spatiotemporal queries can be predominantly spatial or temporal in nature, markedly different groupings of data will be requested by users. Some background is useful to highlight the difficulties of providing this flexibility.

### TABLE 1.
Potential Temporal GIS Capabilities

<table>
<thead>
<tr>
<th>Inventory</th>
<th>Store a complete description of the study area, and account for changes in both the living world and computer storage.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analysis</td>
<td>Explain, exploit, or forecast a region's components and processes.</td>
</tr>
<tr>
<td>Updates</td>
<td>Supersede outdated information with current information.</td>
</tr>
<tr>
<td>Quality Control</td>
<td>Evaluate whether new data are logically consistent with previous versions and states.</td>
</tr>
<tr>
<td>Scheduling</td>
<td>Identify or anticipate threshold database states, which trigger some sort of action by the system.</td>
</tr>
<tr>
<td>Animation</td>
<td>Display a dynamic summary of regional processes.</td>
</tr>
<tr>
<td>Static Mapping</td>
<td>Display spatiotemporal facts by traditional cartographic means.</td>
</tr>
</tbody>
</table>
Current Hardware Constraints

Presently, most stored data reside on magnetic disk. A critical objective in database design today is to minimize the number of disk accesses that the system must make because the slow rate of retrieval from remote memory negates most processing efficiencies in main memory. Frank (1988) elaborates: One mainframe disk access requires approximately 30 milliseconds (one millisecond = a thousandth of a second) and can involve 512 to several thousand bytes (depending on the system). In contrast, an operation within main memory requires approximately 0.1 microsecond (one microsecond = a millionth of a second) and involves generally four bytes (depending on word size). The difference in speed would be 300,000 to 1 if the same amount of data were involved in the two procedures. Even allowing for the different amounts of data involved, the difference in speed between disk accesses and main-memory operations easily exceeds 10,000 to 1.

Understanding the mechanics of data retrieval is essential to understanding system design needs. To satisfy requests for information, a system must first locate where the desired data are stored. Then the system retrieves the data by bringing them into main memory from storage. But data are not simply plucked from storage and transferred to memory. Within storage, all data are clustered into “pages” or “buckets” whose size is defined by the system designer based on the hardware and software involved. To transfer data to or from memory, an entire bucket is transferred, even if the desired data occupy only a fraction of that bucket. If the requested data occupy fractions of many buckets, all of those buckets must be retrieved in their entirety.

For this reason, strategic clustering is critical to acceptable system performance. Ideally, data are clustered in the groupings in which they will be requested most frequently or urgently. Some aspects of GIS operations—for example, quality checks and global searches—are unaffected by clustering because they operate on the complete database, meaning that algorithms can be designed to take data in the order in which they come. However, some GIS functions access only a small subset of the database. These functions often are responses to ad hoc queries. While ad hoc queries are by no means the sole or even the most important GIS function, they generally occur interactively, which makes sluggish response unacceptable. For this reason, system designers must strive to expedite query processing.

The Many Faces of Spatiotemporality

The constraints of physical data management mean that clustering data strategically on disk can improve system response to queries. Rotem and Segev (1987), in considering physical organization of aspatial temporal databases, conclude that no single structure dominates another because suitability depends on the data themselves and on the access patterns (also see Kent 1982). It is worth while to address these two topics in turn.

Imagine that GIS data reside in a hypothetical space defined by two spatial and one temporal dimensions. This discussion will use the physics term “phase space” to describe this hypothetical space. If the data used by different GIS applications were mapped to this phase space, it would soon become apparent that “spatiotemporal” is not a precise term when applied to data forms and groupings. Within the “spatiotemporal” class, we may see horizontal planes of data in phase space that represent the snapshot sequences commonly used in landscape change detection (Figure 1a). Alternately, we may see vertical columns of data with minimal horizontal coherence (Figure 1b). Or we may see a mixture of the two, where the data in phase space have coherence in both horizontal and vertical directions (Figure 1c).

Aside from the character of the data, many different types of queries can be classed “spatiotemporal” (Table 2). A spatiotemporal GIS must be equipped to respond to all queries, but it may favor those types of queries that are more frequent or urgent.

In sum, a temporal GIS faces a broad spectrum of possible data configurations and queries, all under the auspices of “spatiotemporal.” Considering that data are transferred from storage to memory in buckets, and that each bucket retrieved is costly in terms of overall pro-
cessing speed, it becomes evident that data should be clustered into buckets based on anticipated retrievals.

The different characteristics of spatiotemporal systems implies that a monolithic clustering scheme may not be entirely satisfactory. A single clustering strategy can produce equally good results for all applications only by compromise. To produce the best possible performance for a given application means clustering the data to meet its specific needs. Proximity in space and time is but one indication of how data should be clustered; attributes of the data also can be important. Since attribute occurrences can be mapped to a multi-dimensional phase space that includes attribute axes, techniques similar to those described earlier can be applied to visualize clustering requirements for attribute values. For simplicity, however, the discussion that follows addresses the space and time dimensions alone.

**Dimensional Dominance Defined**

The appropriate clustering of spatiotemporal data depends on the groupings in which they will be accessed. Therefore, a critical question is how different applications will use spatiotemporal information. When one dimension dominates another, data can be clustered accordingly to improve system performance.

A spatiotemporal system is merely a system whose phase space includes spatial and temporal axes. Within that broad class of systems are subclasses. Data can be configured in phase space in a space-dominant, time-dominant, or truly spatiotemporal (i.e., equally weighted) pattern. Similarly, queries to the stored data also can be space-dominant, time-dominant, or truly spatiotemporal. These sub-groupings are useful in identifying the precise nature of an application with respect to its data processing requirements.

It is possible to classify spatiotemporal applications according to dimensional dominance of access patterns (Figure 2). As with most broad generalizations, a classification can change with the particulars of an application. In Figure 2, some applications would shift from one class to another if we were to consider the dimensional dominance of the data used rather than the access patterns.

**TABLE 2.**

<table>
<thead>
<tr>
<th>General Spatiotemporal Queries</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Examine a feature's lifespan.</td>
</tr>
<tr>
<td>2. Examine a single time slice.</td>
</tr>
<tr>
<td>3. Examine a feature's lifespan; when the feature meets some criteria, examine its time slice.</td>
</tr>
<tr>
<td>4. Examine a single time slice; examine the lifespans of features meeting some criteria.</td>
</tr>
<tr>
<td>5. Examine the lifespans of all features.</td>
</tr>
<tr>
<td>6. Examine all time slices.</td>
</tr>
</tbody>
</table>

These queries do not correspond to the illustrations of Figure 2, but rather are a generalized set of potential queries for a temporal GIS to treat.
FIGURE 2.
The dimensional dominance of various applications. Even within a given application, variations in focus or purpose can move it from one level of dimensional dominance to another.

1. Where was point P at T_i?
2. What polygons contained point P between T_i and T_j?
3. Where was object O's centroid between T_i and T_j?
4. When and where have polygons larger than S existed?
5. How has a region changed between T_i and T_j?
6. Does change exhibit spatial pattern?

Topographic mapping would remain decidedly space-dominant, but navigational charting and (in some instances) cadastral mapping would shift to the spatiotemporal subclass. Navigational charts are continually amended to incremental "Notice to Mariners" updates, while permits and licenses provide similar incremental updates to land-use mapping (Vrana 1989).

Space-Dominant Applications

Map and chart producers generally are interested in present-tense data and most of their operations are limited to the spatial domain. Despite the space-dominance of mapping and charting, a past tense is available in the form of past editions and incremental updates. Aside from archival purposes, the past has value to map and chart producers. Certain types of feature changes are unlikely, so feature histories can be used in validity checks. In addition, a system that traces past chart and database states provides some protection against unreasonable lawsuits stemming from disputed chart information. Access to the past and future also provides production benefits. Rhind et al. (1983) used known and forecast rates of change to improve production scheduling. And navigational chart producers, who often receive early notice of planned changes to navigation aids and port facilities, could post these changes to a future tense that would be absorbed into the present-tense database as time advances. Thus, production mapping and charting can be considered space-dominant but not atemporal. Other applications with similarly space-dominant queries are transportation, cadastral, and utility mapping. A reasonable design for such systems is to cluster for spatial access but to provide links into the past and future.

Time-Dominant Applications

Just as few space-dominant applications are wholly atemporal, few time-dominant applications can be considered entirely aspatial. Arguably, most applications are enriched by access to their spatial components. For example, medical recordkeeping, personnel tracking, and sales are cited in the science literature as likely candidates for temporal databases. But a regional hospital that can evaluate the medical histories of its patients by location of residence or workplace may achieve a better understanding of location factors of disease. And a corporation that traces where, as well as when, its employees go when they quit, can attempt to understand the factors that draw them elsewhere. Finally, access to spatiotemporal sales figures may describe purchasing cycles and patterns that can assist firms in stocking and warehousing decisions. An information system for these applications would be optimized for spatiotemporal queries, but it also should support spatiotemporal analysis.

Spatiotemporal Applications

The most intriguing spatiotemporal applications favor neither space nor time. Some involve regional processes or
changes in land use or land cover. Others derive their data from real-time sensors or simulation. Examples include electronic navigation charts that track a vehicle's progress; environmental monitoring or modeling systems that study the dispersion, diffusion, or mixing of air, water, pollutants, or sediments; and management systems for natural, human, or military resources that provide a longitudinal view on a region and permit analysts to play out given scenarios. Because such systems must access data across both space and time, their design is quite challenging.

Clustering Considerations

Understanding the emphasis of an application is but the first step in spatiotemporal system design. The next step is to organize data according to the needs of its application, which returns us to clustering. One reason that clustering is vital to a temporal GIS is that it must accommodate queries that request all data in a range or class of values. These queries are termed “range queries” by Knuth (1973) and “orthogonal range queries” by Bentley and Friedman (1979).

Simple queries reference but a single data record. In one common retrieval scenario, the system finds the requested record by consulting a small index in main memory that refers the system to a segment of a larger index in storage. The system retrieves that portion of the index, identifies the storage location of the desired data, then retrieves the data. By this means, any data record can be retrieved in two disk accesses. But range queries are less easily processed because they must locate and retrieve a set of records based on value. Excessive trips to storage are needed if the requested records are not clustered in data buckets.

If we agree that spatial and temporal range queries are critical to a spatiotemporal system, we can defer discussion of the attribute dimensions. A simple spatial range query asks: What lies within a given region defined by x and y ranges? A simple temporal range query asks: What is the history of a single entity over a range of time? Clustering of spatial neighbors expedites spatial range queries; clustering of temporal neighbors expedites temporal range queries. Unfortunately, everything cannot be clustered with everything else.

More data dimensions mean more clustering options. One-dimensional data tend to have some natural order (e.g., numeric or alphabetic) that guides clustering. But multi-dimensional data do not fall neatly into one order or another because no single natural order exists (see Goodchild and Grandfield 1983).

Consider the tangle of one-dimensional yarn that would result from unraveling a two-dimensional knit scarf. If that scarf were a geographic region, how could we organize the stream of digital data so that, given a location on the scarf, its corresponding linear segments are easily referenced? Adding a third dimension, be it spatial or temporal, makes matters worse. A related three-dimensional analogy is to organize a strand of yarn so it is possible to reconstruct the cloud of wool from which it was spun.

Even if a single natural order does exist, as with time, several representational options are available. Dadum et al. (1984) describe the possibilities (Figure 3). While one approach may not serve all purposes equally well, criteria for choosing

FIGURE 3.
Methods of ordering temporal data. (1) Time slices stored as snapshots, (2) backward-oriented amendments to a base state, (3) backward-oriented cumulative amendments, (4) forward-oriented amendments to the base state, (5) forward-oriented cumulative amendments.

<table>
<thead>
<tr>
<th>Space-dominant</th>
<th>Spatiotemporal</th>
<th>Time-dominant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topographic mapping</td>
<td>Simulation modeling</td>
<td>Maintaining medical or legal case histories</td>
</tr>
<tr>
<td>Navigational charting</td>
<td>Human, environmental, or military resource management</td>
<td>Personnel and inventory recordkeeping</td>
</tr>
<tr>
<td>Utility mapping</td>
<td>Electronic charting</td>
<td>Recording car and gun ownership histories</td>
</tr>
<tr>
<td>Cadastral mapping</td>
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</tbody>
</table>
one approach over another do exist.

Time can be represented absolutely or relatively. An absolute representation is a snapshot series (e.g., Figure 3, line 1), an approach that wastes space and represents spatiotemporal facts poorly. To implement a relative spatiotemporal representation requires that a base state be established from which amendments depart. Dadum et al. describe a base state to be the oldest or the most current data, which amendments modify; a third option not addressed by Dadum et al. but noted in Lum et al. (1984) is a base state with both forward- and backward-oriented amendments to describe both past and future tenses.

The application dictates which base state to select. A likely construct is to designate the most current data available as a base state, with outdated data comprising a past tense and forecast data comprising a future tense. Map or chart producers may prefer the base state to be the date of the last map or chart edition produced in that area, which would place the uncharted amendments that occurred since publication in the future tense. And still others, for example historical or archaeological researchers, may elect to establish a particular past date being studied as the base state.

A second design decision concerns how amendments modify a base state. Fully superseding amendments are the strategy of choice for most applications because they work for all data types, nominal and otherwise. Alternately, amendments can supersede base-state information or, when data are not nominal, the amendments can accumulate from the base state. The allure of cumulative amendments is their compactness; however, compaction comes at a price, since the value at any given moment must be reconstructed from the base state and interceding values.
Temporal Relational Databases

A second interesting example of designing for dimensional dominance arises from the aspatial database literature. In this aspatial literature, "state-dominance" substitutes for "space-dominance" because in both cases, it is snapshots of single states in time that are of primary importance. Many contrasting approaches exist; classifying them according to dimensional dominance clarifies their distinctions (Figure 6).

A traditional temporal database approach is to generate database snapshots and describe interim transitions via transaction logs. Similarly, the table-based methods (e.g., Clifford and Warren 1983) are relatively state- or space-dominant (Figure 6a); a change to any field in a table results in a new table. However, both these methods become untenable if the database is large or if temporal depth exceeds several states. Space-dominant storage such as this also presents a challenge to longitudinal analysis.

It is possible to represent time as an attribute of space. The space-time composite (Langran and Chrisman 1988) achieves this end by generating a set of greatest common spatiotemporal units using polygon overlay methods. This method of representing spatiotemporal information is time-dominant because a single field clusters all versions of the attribute stored in that field. Figure 6c sketches an attribute-based method where each time-varying field of a tuple holds a variable-length list of values and effective dates. Ferg (1985) ascribes the same problems to attribute-based approaches as to transposed files in general: columns of data (i.e., one attribute value for each tuple) are easy to retrieve but retrieving rows of data (i.e., all attribute values for a single tuple) is relatively slow because the former are grouped together, both logically and in storage. Attribute-based methods provide the highest level of temporal detail with the most clustering, making them suitable for time-dominant applications.

Several tuple-based representations exist and each would place a different emphasis on space relative to time. Those that remain transaction data within tables (e.g., Snodgrass and Ahn 1985; Ariav 1986) could support...
FIGURE 5.
Methods of storing a temporal grid. (a) A space-dominant grid stored as a snapshot sequence; (b) a time-dominant grid stored as lists of cell values; (c) a hybrid spatiotemporal arrangement with the base state stored in space-dominant form and historical data stored in time-dominant form.

Case Studies of Dimensional Dominance

The preceding discussion on dimensional dominance emphasizes the individuality of temporal GIS user requirements. We can legitimately ask whether a single system can meet the needs of all users. Many atemporal GIS designs exist; is it reasonable to expect a single temporal GIS design to be adopted by all applications?

A single spatiotemporal database design is unlikely to be optimal for all applications; however, case-by-case design is equally undesirable. A better approach is to study the optimal solutions for meeting different requirements, then seek unifying characteristics that can serve as guidelines in subsequent database and software design. When unifying characteristics do not exist, a modular approach could improve the likelihood of one system being usable by all. If temporal GIS data structures, functions, and displays were designed to adjust to various levels of dimensional dominance, a designer who was aware of an application’s use of space and time could tailor generic methods accordingly.

The next step, then, is to consider the optimal data organization for space-dominant, time-dominant, and spatiotemporal applications. Because a comprehensive approach would be an overly ambitious undertaking, this exploratory discussion resorts to case studies.

Three case studies serve to illustrate structural adaptations. The first case study, a temporal grid, provides a conceptually simple illustration of clustering options. The second case study presents design options for temporal relational databases. The final case study examines nautical charting, with queries that are space-dominant but with data that are time-dominant. The incongruent dimensional dominance of queries and data in nautical charting is a troublesome but common problem of geographic applications that temporal land information systems also face.

Temporal Grids

A grid, the simplest geographic data structure, provides a suitable vehicle to introduce methods of clustering for dimensional dominance. A temporal grid (Figure 4) can be clustered in storage in several different ways (Figure 5).

A space-dominant approach would provide snapshots of the grid over time (Figure 5a). This approach is the one in common use for detecting changes between sequent Landsat images. Each image is stored separately and in its entirety. A time-dominant approach would cluster all the values over time held by a single grid cell (Figure 5b).

Logically, a spatiotemporal approach would cluster small cubes within the space-time cube. However, an alternate method may produce better results for many spatiotemporal applications. By storing the base state and other frequently referenced periods in space-dominant form, then storing all amendments in time-dominant form (Figure 5c), the ranges lying in the most-traveled paths are clustered. If each value changes at each time slice, this method does not improve upon the space- or time-dominant alternatives; the assumption, however, is that change is asymmetric.
true spatiotemporality because all space and time data are grouped together and are equally accessible or inaccessible. Figure 6b sketches such a method, where all versions of tuples are stored together in a single table. Conversely, the Lum et al. (1984) method (shown in Figure 6d) stores a space-dominant base state with time-dominant amendments and addresses spatiotemporal needs in a way similar to the compromise spatiotemporal method described previously (and illustrated in Figure 5c).

Ahn (1987) notes that it is possible to convert a tuple-based to an attribute-based representation, and vice versa. Likewise, it should not be difficult to convert between space-dominant, time-dominant, attribute-dominant, and hybrid representations. (Nyerges [1989] suggests that variation in dimensional dominance is an important consideration in a modeling exercise.) If a time-dominant analysis is to be performed on a small subset of data organized for space-dominance, converting the data to the appropriate dimensional dominance before performing the analysis is one design option to explore. In all cases, however, frequent transformations represent undesirable overhead.

**FIGURE 7.**
A space-dominant strategy for chart production. Changes cause the area to decompose over time into a space-time composite comprised of the greatest common spatiotemporal units. Periodically, the space-time composite is recomposed into a snapshot, extracted, and stored to improve system responsiveness to space-dominant queries.

**Chart Production**
A final case study examines the spatiotemporal needs of a chart producer. Unlike applications with a space-dominant present tense and a time-dominant past tense, many of a chart producer’s updates are time-dominant amendments to existing features that are amenable to being represented by a space-time composite. However, the chart producer’s queries are likely to focus on space-dominant investigations of the appearance of an area (or of the database’s contents concerning an area) as of a given date. To meet space-dominant query needs while accommodating the data’s temporal depth, the space-time composite can be recomposed periodically and stored separately to provide a snapshot of the world at meaningful moments (Figure 7). This support of space-dominance in a spatiotemporal system does not expand data...
volumes as much as one might think, since the recomposed "chart" is actually a table of pointers to the same objects used by the space-time composite.

Summary and Conclusions

This discussion by no means exhausts the topic of clustering. Clustering remains an intriguing problem that is associated with multidimensional data of all kinds. Among the key points of this discussion are:

- the concept of dimensional dominance helps to balance the needs of an application against representational realities;
- visualizing data and queries in a multidimensional phase space aids in system design;
- a widely usable temporal GIS can be achieved by finding common ground among optimal solutions and designing the system modularly to adjust for variations in dimensional dominance.

The theoretical and conceptual facets of temporal GIS design must join with the realities and limitations of technology to produce a realistic strategy for implementation. While conceptual designs enjoy a certain level of timelessness, implementation issues and their proffered solutions are firmly rooted in the constraints of contemporary technology. Clustering is among the more immediate technological barriers to overcome for temporal GIS to become a reality.

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Visualizations: Linking Dynamic Spatial Models with Computer Graphic Algorithms for Simulating the Effects of Resource Planning and Management Decisions

Randy H. Gimblett

Randy Gimblett is an assistant professor of landscape architecture at Ball State University in Muncie, Indiana. His research interests involve the use of GIS and remote sensing techniques for dynamic spatial modeling, environmental perception, and merging advanced technology for modeling changes within ecosystems. His most recent research involves linking neural modeling, genetic algorithms and non-traditional artificial intelligence techniques with dynamic GIS for modeling impacts on ecosystems.

Abstract: The explosion of information associated with current geographic information system (GIS) technology is having a significant impact on the quality and effectiveness of land planning and management. While current applications incorporating GIS technology have clearly illustrated its importance and viability as a mechanism for improving program management and short-term decision-making, it is limited by its inability to handle the complex associations of information essential to modeling the dynamic interactions of ecological systems. Since traditional modeling approaches are primarily deterministic and lack the ability to respond to changing environmental patterns, they do not accurately represent or portray future implications of land planning strategies. The purpose of this paper is to describe a framework known as the Integrated Resource Assessment and Simulation Systems (IRASS) developed to link dynamic spatial models with enhanced computer graphic algorithms to convey the effects of planning and management decisions on the landscape over time.

The explosion of information associated with current geographic information system (GIS) technology is having a significant impact on the quality and effectiveness of land planning and management. To plan and manage land effectively, information is needed that is both accurate and appropriate for modeling biophysical problems. In addition, this information must be easily maintained and updated to incorporate current information from a variety of sources.

Current applications incorporating GIS technology have clearly illustrated its importance and viability as a mechanism for improving program management and short-term decision-making. However, one of the major limitations current GIS technology faces is its inability to handle the complex information that is essential to modeling the dynamic interactions of ecological systems. Within the simplest of ecosystem models, state descriptors change with every time step, resulting in tens of thousands of state changes. Current GIS technology simply cannot handle these complex interactions.

The complexity found within natural systems is represented by hierarchical interactions that exhibit both spatial and temporal elements. Current modeling techniques have not resulted in realistic simulations due both to limitations in machine architectures and lack of appropriate algorithms for handling the complexities of natural systems. An ecosystem, by definition, is dynamic, and traditional modeling approaches provide only a static representation. Much of the information inherent in a real biophysical system is dependent upon the temporal-spatial association and spatially dependent interactions of the system components.

Since traditional modeling approaches are primarily deterministic and lack the ability to
respond to changing environmental patterns, they do not accurately represent future implications of land-planning strategies. While applied research undertaken by Itama (1988) and Gimblett (1989) has clearly illustrated the feasibility of linking dynamic modeling techniques, it was severely handicapped by the lack of appropriate computer software. Currently, Ball (1990, 1990a) is examining ways to model the complexity of dynamic systems.

Acknowledging the inadequacies in the earlier work by Itami, Ball has developed a prototype for a spatial dynamic-simulation language referred to as PROMAP. PROMAP was designed specifically for ecological modeling. It is a derivation of raster-based GIS that uses a traditional two-dimensional matrix format. Models that are currently being developed using PROMAP include fire behavior, hydrology, erosion, and forest succession. While the implementation of the fire behavior model has demonstrated the tremendous flexibility for modeling both global and local change, PROMAP’s two-dimensional format becomes a major limitation when trying to examine land-use and ecological phenomena that are three-dimensional and temporally active. We need to improve biophysical models to incorporate spatial dynamic properties in order to examine future implications of planning and management decisions in both urban and regional landscapes.

The purpose of this paper is to describe a framework known as the Integrated Resource Assessment and Simulation System (IRASS) for linking the dynamic spatial models with realistic video imagery to simulate the effects of planning and design decisions for both urban and regional landscapes over time.

Computer Graphic Techniques for Displaying Landscape Simulations

Visual renderings in such media as pencil or oil paint have been used for many years to graphically represent or simulate change in both urban and regional environments. However, it wasn’t until the recent evolution of computer graphic technologies from a variety of disciplines that realistic, dynamic simulations began to appear. Computer graphics have provided a communication medium that is dramatically changing the nature of the design and planning professions.

One area of research and development that has focused on examining change within the physical environment is commonly referred to as “Visualization.” The National Science Foundation recently formed a group to examine user needs in the general field of “Visualizations in Scientific Computing” (McCormick et al. 1987). According to McCormick et al.: Visualizations transform the symbolic into the geometric, enabling researchers to observe their simulations and computations. Visualization offers a method of seeing the unseen. It enriches the process of scientific discovery and it’s revolutionizing the way scientists do science. . . . Visualizations embrace both image understanding and image synthesis; that is, it is a tool both for interpreting image data fed into a computer and for generating images from complex multidimensional data sets. Visualization studies those mechanisms in humans and computers which allow them in concert to perceive, use, and communicate visual information. (p. 63).

Computer visualization techniques, when used to model environmental change, provide resource managers, environmental planners and the general public with a tool to simulate cause-and-effect relationships within ecological systems.

Several approaches for generating visualizations have been developed over the last decade to assist decision-makers and the public in appraising human-induced impacts. McCormick et al. revealed four general approaches to generating visualizations which lend themselves to creating accurate yet realistic appearing images for evaluating resource management problems. Three approaches are selected because they are directly applicable to this research. They are:

• Video imaging
• Computer surface enhancement
• Advanced computer graphic algorithm approaches.

Video Imaging

Thanks to recent advances in computer graphic technology, an added dimension of realism is available by replicating aspects of the real world in constructing video image visualizations. Video digitizing automatically captures and converts an image into
digital format. This enables the enhancement, extraction or manipulation of images in order to convey the future implications of planning or design decisions. The source of the image may be color or black and white photographs, color slides, hand drawings or video tape. The digital image may be rendered or manipulated, using pixel editing software (Orland 1987). Video imaging offers significant advantages over hand-drawn techniques in that it is relatively inexpensive and provides immediate visualizations. However, several problems with this technique limit its general applicability.

For example, scaling components within the image, yet maintaining its realistic appearance, is one problem. Work to date has been rather elementary, using a “cut and paste” approach. Performing primarily simple cosmetic alterations within existing imagery, this technique involves the removal or addition of new static features within an image (Figures 1 and 2). Current techniques are very limited when inserting new elements that must be correctly scaled, placed, and aligned in proper perspective.

Disadvantages in scaling and image accuracy of video imaging, however, are far outweighed by its realism. Traditional techniques, while capitalizing on an artist’s skillful rendering, provide only an abstract representation of reality. The video image visualization essentially is constructed by altering the pixel values to recapture the realism. However, when the video imagery requires a lot of manipulation to examine future change, the realism becomes dif-
difficult to maintain.

Recent work by Daniel and Orland (1989) has employed image-processing techniques to assist in analyzing and defining the pixel patterns from the video-captured image to alleviate the problems found using the "cut and paste" approach. This work, while still in the experimental stage, has clearly illustrated the advantages of incorporating video imaging with quantitative methods for generating visualizations. These analytical methods illustrate the importance of using advanced image processing techniques to resolve the problems of adjoining pixel values within an image.

**Computer Surface Enhancement**

New and exciting applications in video imaging are now being explored using computer-generated wire-frame perspectives and their more advanced color surface modeling relatives by agencies such as the U.S. Forest Service. Computer programs such as PERSPECTIVE PLOT (Nickerson 1980; Twito and Warner [no date]), SCOPE (Warner and Nickerson 1977), and PREVIEW (Myklestad and Wagner 1976) were developed utilizing statistical methods for quantitatively reproducing accurate three-dimensional perspective images. These programs used digitized elevation maps and vegetation data interpolated from a traditional two-dimensional grid matrix. These "special purpose" programs are employed primarily to assist U.S. Forest Service landscape architects in protecting the visual quality of America's national forests. The programs construct three-dimensional views of natural landscapes by calculating the perspective transformation of the gridded elevation, producing a "distorted grid" or "fishnet" perspective view of the landscape (Figure 3). In addition, the models can be surfaced to provide a higher degree of realism than that of the wire-frame image (Figure 4).

A diversity of computer software is currently sold on the market for generating three-dimensional terrain models: SURFACE2, ASPEN, Intergraph's Digital Terrain Modeling (see cover) and, more recently, work outlined by Bauer (1988) using AutoCad and contour mapping from USGS Digital Elevation Model (DEM) to construct threedimensional digital images or terrain relief maps.

Computer-enhanced wire-frame images provide significant advantages over the previously discussed video imaging techniques. First, they provide the decision-maker with a greater degree of flexibility in the selection of viewer position, view angle, and desired target location. Second, the visualization created from the digital terrain model (DTM) is generated using a precise database that is aligned with a geographically referenced coordinate system represented on the earth's surface. The relative accuracy of the DTM is dependent on the source of the original data. Third, data already in digital form, such as digital elevation models (DEM) and satellite data, can provide computer-generated perspectives that are economical and that accurately represent the earth's surface.

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Recent advances have merged GIS or satellite imagery (LandSat TM) with digital elevation data for constructing three-dimensional, false-color composite visualizations. Algorithms have been developed that incorporate LandSat TM data into the GRASS (Geographic Resources Analysis Support System) GIS and then drape them over a three-dimensional surface (Grassclippings 1988). This procedure offers tremendous advantages over the wire-frame perspective in that the LandSat TM imagery and digital elevation models exist in digital format, reducing the added expense of data input. Since satellite data are acquired on a regular basis, visualizations can be constructed to illustrate the temporal nature of the earth’s surface. While this procedure results in major time savings in data handling, it’s disadvantaged by its inflexibility in generating visualizations from a variety of viewpoints, unlike the computer-based wire-frame approach. However, this is assumed to be a current limitation in the system that will be alleviated with future research.

**Advanced Computer Graphic Algorithm**

Research has continued in the development of sophisticated computer graphic algorithms for high-quality surface rendering. Past approaches to surface rendering:

... have primarily ignored the illumination components resulting from light reflected from other surfaces, more elegant, but computationally expensive solutions are available utilizing ray tracing techniques evolved by Appel (1968).

Ray tracing involves:

... tracing a ray of light from a viewpoint through a pixel and into the model where its interaction with objects is analyzed. As the ray strikes the first object in its path, the ray is broken into three components: diffusely reflected light, specularly reflected light and transmitted (refracted) light. Similarly a ray of light leaving the surface of an object is in general the sum of the three components. (McLaren et al. 1989, p. 90)

Ray tracing calculates a new value for each pixel in the image, until the entire image is created. Much of the work up to this point utilizing the powerful ray-tracing surface rendering has been initiated in the industrial and architectural disciplines. However, techniques such as ray tracing can provide high-quality renderings that add the realism of illumination essential for the accurate portrayal of natural environments. Because of the lack of past success in constructing simulations that capture the complex illumination patterns in natural environments, ray tracing seems like the logical choice. In conjunction with certain machine architectures, these algorithms provide added realism with walkthrough capabilities for dynamically simulating movement within the physical environment. These approaches are being extensively explored for creating visualizations within natural environments.

*FIGURE 4.* Example of quick shading to color surface-rendier wire-frame terrain models.
Summary of Approaches

Advances in computer graphic technology, as outlined above for constructing realistic-appearing visualizations, fall along a continuum. At one end of the spectrum are the highly abstract, simple, monochrome wire-frame models; at the other end are the highly realistic appearing, fully textured and colored images in either two- or three-dimensional format. In the former, realism is sacrificed for processing speed; the latter generates more realistic-appearing visualizations but is computationally expensive. While the ideal solution is to produce images that are indistinguishable from reality, there has been very little research and development undertaken to link these technological innovations into an integrated graphic simulation system. The video imagery and computer graphic algorithms such as ray tracing provide the visualization with its realism, and the GIS and wireframe perspective techniques provide the necessary accuracy required for further planning and development work. The next logical step is to integrate the technological innovations described above to provide the accuracy and economy of a GIS modeling/perspective simulation approach with the realism of video imagery and ray-tracing algorithms as a tool for visualizing the dynamic effects of planning and design decisions at both the urban and regional scale.

Integrated Resource Assessment and Simulation System (IRASS)

IRASS emerged from the need to develop a system that can link dynamic spatial models with realistic video imagery to simulate the consequences of planning and design decisions for both urban and regional landscapes. This hypothetical model consists of three interconnected modules:

- Dynamic spatial modeling
- 3-D preview and simulation
- Visualization.

Dynamic Spatial Modeling

Much of the work to date in the area of geographic information systems has focused on the development of more efficient algorithms, raster and vector conversions, usage of powerful spatial analytical operators and elegant graphic display. While these GIS tools provide a mechanism to adequately understand the availability of biophysical resources in a region, there are two apparent shortcomings that are addressed by IRASS in this research. First, researchers and modelers using GIS have failed to respond to the inadequacies and gross error in using static analysis tools to model complex and dynamic natural systems. This has led to a proliferation of static planning solutions that do not accurately represent real-world conditions. Secondly, much work to this point has focused on developing techniques to display two-dimensional map output, failing to recognize the importance of three-dimensional graphic representations for visualizing the results of spatial-modeling scenarios.

To solve these and other problems that plagued regional planners modeling the complexity of dynamic systems, IRASS utilizes a prototype for a spatial dynamic simulation language referred to as PROMAP. PROMAP was designed primarily for ecological modeling. It uses a traditional two-dimensional raster-based format like its predecessor, Map Analysis Package (MAP), but incorporates a reduced instruction set and works with real numbers. PROMAP is an outgrowth of investigations that link cellular automata approaches within a GIS framework through a series of new operators: MATH, TERRAIN and CELL (Ball, 1990, 1990a). The implementation of PROMAP within IRASS provides the modeler with unique analytical capabilities for developing and implementing dynamic models to aid both short- and long-term decision-makers. PROMAP allows the modeler to program specific cells within the matrix to model change at both the local and global level. The output from the implementation of PROMAP is two-dimensional raster maps (Figure 5).

3-D Preview and Simulation Module

While modeling of complex systems can be analyzed using PROMAP, the two-dimensional map display fails to visually capture and convey the dynamics of this analysis. As a result, the three-dimensional...
preview and simulation module was implemented: (1) to preview a view that could be replicated over time, and (2) to portray the view using computer graphic surface-shading algorithms.

The preview module uses the algorithm SIM-TERRAIN, developed for creating a three-dimensional map surface. SIM-TERRAIN combines the elevation values from a topography map with a map that is generated through the execution of a dynamic model in PROMAP to produce a three-dimensional wire-frame gridded surface. This three-dimensional image is merged into a design file format for further processing.

From the three-dimensional image file, perspective views can be generated representing any desired position on or above the surface of the terrain model and to any significant position that is to be viewed. This process is currently handled within MODELVIEW (Intergraph 1988). MODELVIEW is a shell containing a number of algorithms for manipulating images in wire-frame or using ray tracing, a sophisticated surface-rendering technique. Once the view specifications are complete, MODELVIEW is used to generate a wire-frame perspective to preview the image. This perspective view may be color-rendered to illuminate the patterns that define the surface of the three-dimensional terrain model. This approach has advantages over the previous video imaging and terrain modeling approaches in that it is extremely flexible for generating perspective views from virtually any position within the vicinity of the terrain model.

The power of the simulation procedure resides in the ability to link the three-dimensional wire-frame model to computer-aided design and drafting (CADD) systems. Within a CADD environment, three-dimensional wire-frame images are constructed that reflect commonly used design features found in both natural and man-made environments. These include such features as building styles, various types of vegetation, light standards, roads, cars, bridges, etc. Within the CADD environment, each of the features are designed individually at their appropriate built scale. The wire-frame design features generated in the CADD environment are totally compatible with the three-dimensional surface model. These three-dimensional features or elements are referred to as “cells” and are stored in what are known as “cell libraries.” These “cell libraries” are attached to any three-dimensional design file so that any cell may be selected, displayed and placed in the same file.

The three-dimensional surface of the model that has been constructed is comprised of composite weighted values pertaining to some known set or sets of biophysical conditions. Algorithms were developed that examine the
range of values and automatically place appropriate 3-D wire-
frame cells stored in the cell library onto the surface of the
terrain model in accordance with these values. In the case of the
vegetation, the algorithm finds the value on the three-
dimensional surface that represents the identical vegeta-
tion species, searches through the cell library to find the desired
cell, and randomly scales, rotates and then places the cell onto the
surface of the model. Landscape standards such as number of
units per acre, orientation, zoning setbacks, ordinances and
property boundary allotment can be included into the algorithm
for further design refinement. At the current time, the algorithm is
limited to placing one element per cell of area representing the
model’s surface. Color-surfacing rendering can subsequently be
performed on the terrain model. If the wire-frame cells need to be
relocated, they are easily moved using the CADD system according
to more precise site-planning criteria.

Visualization Module

The visualization module uses the sophistication of computer
graphic algorithms to render the three-dimensional images generated in the preview
and simulation module. Instead of using the computer-generated
surface rendering for the final representation of the image, the
realism is created using a ray-
tracing and texture-mapping pro-
cess. The texture-mapping pro-
cess utilizes previously captured
two-dimensional video images or
textures, but maps them onto
three-dimensional surfaces. These
textures are video digitized or
scanned and subsequently stored in
what are referred to as “image libraries.”

Texture mapping to sur-
face the three-dimensional model
is a two-step process. First, a
lookup table must be created,
which defines both the textural
qualities desired and the video
textures for each of the wire-
frame surfaces of the image being
rendered. Textural qualities may
be defined in the lookup table by
specifying both the color and one
of the following: reflectance, mirror-
ing, dullness, shine and trans-
parency. Second, using the ray-
tracing algorithm and corre-
sponding lookup table, the quali-
ties of each set of pixel values
representing the surfaces of the
wire-frame image are calculated
to derive the appropriate illumina-
tion value. This illumination
value is based on current lighting
conditions and the pixel’s posi-
tion in relationship to all other
surfaces defined in the image.
The result, although computa-
tionally expensive (depending on
the number of vectors being pro-
cessed in the image), is a visuali-
ization of near photographic
quality.

The application of the in-
tegrated framework as presented
in this paper will alleviate many
of the problems encountered in
the past generation of visualization.
The application of IRASS
provides the following advan-
tages over previously used tech-
niques:

- Resource overlays, satellite infor-
mation and data gathered from a
variety of mapped sources, linked
to a geographically referenced
coordinate system representing
known points on the earth’s sur-
face, increases the accuracy and
credibility of the visualizations.

- The evaluation of three-
dimensional terrain models pro-
vides an accurate method for
validating and verifying resource
data.

- Incorporating the powerful spatial
analytical capabilities of PRO-
MAP allows sophisticated
dynamic modeling of both global
and local changes within a known
biophysical environment.

- Computer graphic algorithms
such as “ray tracing” and texture
mapping, combined, alleviates the
scaling problems encountered in
traditional video imaging ap-
proaches. In addition, using video
textures gathered in the local
areas for surfacing the three-
dimensional models increases the
“believability” and authenticity of
the visualization.

- With the availability of most
computer graphic systems to output
directly to a VCR via an RGB
interface, new and exciting tech-
niques are being explored to pre-
sent long-term planning and
management decisions to the
public.

- Linking the PROMAP simulator
with a CADD system for
developing and automatically
placing three-dimensional wire-
frame “cells” revolutionizes tradi-
tional approaches for accurately
conveying future planning and
management decisions.

- The use of sophisticated ray-
tracing algorithms for surface
rendering adds to the image
crucial illumination qualities im-
portant for ensuring its authentic-
ity.

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Conclusion

The role of visualizations has dramatically changed over the last decade. The increase of research and development into the use of computer graphic technology in the planning and design disciplines has created new and exciting opportunities for conveying both short- and long-term implications of planning and management decisions on the land. There are far too many bad examples of abstract, unrealistic visualizations presented to the public that convey a false image of future planning and management decisions. This practice, according to Itami and Daniel (1987), has “led to a lack of credibility and questionable reliability in the results of such efforts.”

With an interactive approach presented in this paper that utilizes the powerful PROMAP simulation system in combination with a CADD system and sophisticated computer graphics algorithms, a new age of computer-generated visualizations is dawning. Current work is still in pursuit of artificial visualizations that replicate and bring to life the complexities found in natural environments. One of the exciting directions currently being explored is with neural modeling and genetic algorithms. This work, although too early to tell, suggests exciting possibilities for incorporating biophysical models with behavioral models in order to explore human impacts on fragile ecosystems.

If decision-makers are serious about developing reliable, accurate systems that incorporate the accuracy of a GIS database and that produce realistically appearing visualizations for analyzing and conveying a broad range of resource issues, then it is imperative that connections be made between dynamic GIS and such techniques as video imaging and ray tracing as presented in this paper.

Acknowledgement

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References


Adapting and Applying Existing Urban Models: DRAM and EMPAL in the Seattle Region

W. T. Watterson

W. T. Watterson is director of technical services and economist for the Puget Sound Council of Governments in Seattle, where he is responsible for the economic, demographic, and travel forecasting and data collection programs, as well as the agency computer center. In about ten years at the agency, he has developed regional econometric and urban activity model systems, several economic and demographic data collection and estimate programs, and the integration of activity and travel-demand model applications. He has a Ph.D. from the University of Pennsylvania, and a M.R.P. from the University of North Carolina.

Abstract: DRAM and EMPAL are urban activity simulation models used in several metropolitan regions around the United States. In the Seattle region, these models have been adapted and applied to projects of the metropolitan planning organization. This paper outlines the models and their modifications and enhancements for Seattle, summarizes the calibration of the latest versions, and briefly describes some of the forecasting and analysis projects to which the models have been applied. The overall assessment is one of successful adaptation and use of models, but with a necessary premium on continuing evolution, development, and learning.

Urban models represent a bold attempt by social scientists to capture the essential dynamics of metropolitan regions into a figurative mathematical jar. Such models—variously known as urban activity, urban simulation, urban development, and land use models—are designed to allocate households and employment to sub-areas throughout a metropolitan area, based on some set of variables and their parameters estimated on actual historical data. The models are used for forecasting future urban development and for simulating and analyzing potential changes in policy or infrastructure. This paper concerns one set of urban activity models—DRAM (Disaggregated Residential Allocation Model) and EMPAL (Employment Allocation Model)—that are in use in several metropolitan areas at this time.

Local Historical Perspective

At the Puget Sound Council of Governments (PSCOG), the traditions of using models in forecasting development and land use activity run deep. Even before the general use of computers in the 1960s, the long-range forecasts for the transportation study and rapid transit feasibility were based on a multivariate model of urban development. In 1972, the PSCOG invested in the installation and estimation of the EMPIRIC model, which was in use for forecasting and some analysis throughout the rest of the 1970s. In 1980, an operational version of the DRAM and EMPAL models was acquired from another region to replace EMPIRIC. Over the years since 1980, this version has been progressively restructured, reprogrammed, and enhanced in order to keep pace with the needs of the agency program.

From this abbreviated history, it should be clear that the question of whether population and employment forecasts should be done with models at all has never been much at issue in the Puget Sound region. To be sure, there are plenty of antagonists and naysayers about any set...
of forecasts and about the models being used. But these skeptics would be just as critical of non-model forecasts and methods. The use of urban models is well-accepted and even expected by the planning culture in the region, as somehow producing better and more objective results than mere humans could. (And in other regions as well, as Janet Pack (1978) has documented). Whether this is in fact true, and true for both forecasting and analysis work, is of course an interesting and important question; I will return to this question later in this paper.

Focusing for the moment on the reasons for converting from EMPIC to DRAM/EMPAL, let me first state that these involved both the oft-cited condemnations of EMPIC and the practical requirements of the PSCOG program. EMPIC at the PSCOG was designed particularly for the needs of land use forecasting and inputs to the travel demand models. It fulfilled these roles quite well, at least in the funding environment of the 1970s. However, its input data requirements and its run costs were prodigious, and its flexibility and analytic capabilities were almost nonexistent.

The EMPIC model is a set of best-fit difference equations statistically estimated from a large set of raw data on two base years. Its “structure” depends on what variables best explain urban change in the base period. Forecasting with EMPIC required an extensive set of exogenous data for the future years, such as the area within each zone to have sewer service and a comprehensive “amenity” index for each zone. The fact that a single run of the entire model (on a time-shared computer) could cost hundreds of dollars effectively limited the use of the model to periodic forecasting projects (even in an era of substantial federal funding support). As if these factors were not enough, in the few instances when EMPIC was applied to analytic purposes, it failed to produce reasonable impact results even in response to some major policy alternatives. This problem of the model has been extensively documented by Stephen Putman (1979), Janet Pack (1974), and other researchers.

By 1980, DRAM and EMPAL appeared to offer an attractive alternative to EMPIC at the PSCOG. These models had been developed and tested for some years in a university research setting by Steve Putman and his associates at the University of Pennsylvania. They are descended from the Lowry/PLUM line of urban models, which, in contrast to EMPIC, are structured around home-to-work transportation accessibility for households. DRAM represented a considerable expansion and estimation improvement over earlier models. DRAM and EMPAL have recently been applied at the Mid-America Regional Council, though not with final success. For the PSCOG, they offered the poten-

Horwood Critique Articles

In 1985, URISA established the Horwood Critique Prize in memory of Dr. Edgar Horwood of the University of Washington, who founded URISA in 1966. The objective of the prize is to challenge information systems professionals to more critically interpret developments in the field. The prize is given annually to the author(s) of a paper published in the previous annual URISA Proceedings representing the best critical analysis of an urban, federal, regional or local system design; implementation or application; technology policy or issue; or contextual environment.

Papers are judged on their candor, critical insights, and conclusions and methods employed in the critique. All papers appearing in the Proceedings are judged in the competition. To share these outstanding papers with a wider audience, we are featuring the 1989 Horwood winner, “Adapting and Applying Existing Urban Models: DRAM and EMPAL in the Seattle Region” (Watterson, Vol. IV, p. 78) in this issue.

In keeping with the critical intent of these papers, we invite comments and responses to all four Horwood Winners (1986–89). Selected responses will be published in an upcoming issue of the Journal.

The Editors
tial for simplifying the zone structure and input data for calibration. They could be calibrated and run for a fraction of the computer costs of EMPIRIC operation. DRAM and EMPAL had a reasonably good research track record in analytic capability, and could probably be made to forecast as well as EMPIRIC, both for inputs to travel demand models and for reviewable population and employment forecasts. Finally, they appeared to have a flexibility and malleability (lacking in EMPIRIC) for adapting to changing needs and conditions in future years.

Since the time of their original application at the PSCOG, DRAM and EMPAL have been calibrated three times on two different computer systems, used for three extensively reviewed sets of population and employment forecasts, and applied as simulation models to several difficult impact analysis problems. Along the way, the models have been substantially restructured and enhanced to meet the particular needs of the forecasting and analysis program at the PSCOG. All of this has been accomplished at the greatly reduced funding levels that have been the reality of the 1980s. Overall, DRAM and EMPAL have met the original objectives about as well as could have been hoped for, and better than any other model in its class could have.

The rest of this paper presents some of the key aspects of the DRAM and EMPAL experience at the PSCOG, including the changes that have been made in the models, a summary of the 1985 calibration results, some examples from the forecasting and analysis experience with the models, and the directions that activity modeling may take at the PSCOG in the future.

Adaptations to DRAM AND EMPAL

One aspect of the application of DRAM and EMPAL in the Puget Sound region is the types of adaptations to these models that have been made progressively since the original installation at the PSCOG in 1980-81. These changes are summarized in this section. For a description of the basic structure of DRAM and EMPAL, the reader is referred to the extensive writings of Stephen Putman on the subject, especially Integrated Urban Models (1983).

Structural Modifications

Three different types of structural changes have been made to the original DRAM and EMPAL models. One is the use of two time periods for parameter estimation, rather than strictly as a single-year cross section. The net effect is to bring the calibration time periods into line with the forecasting time periods, producing a recursive, quasi-dynamic model system.

A second modification involved the elimination and consolidation of several variables in the models because of statistical problems in parameter estimation, particularly problems of collinearity. What resulted was perhaps a less theoretically appropriate model structure, but a better set of estimated parameters for forecasting and simulation.

Related to this were some additions and changes in variables representing the locational attractiveness of each zone in order to improve the simulation capabilities of the models. The objective here was to introduce and/or respecify variables which would better the long-term dynamics of the models' predictions, and which would make the models more sensitive in analyzing impacts of land use and policy changes in subareas—with a criterion of at least improving the model calibration at the same time.

The original EMPAL attractiveness index contained only one industry sector (both current and lagged), and only one land use variable. In moving to two time periods for calibration, we added all other industry sectors' lagged employment levels as attractors, in order to gain some interaction among sectors. Since this captured only the same zone effects, we constructed a simple gravity index of proximity to employment in nearby zones for an interzonal employment interaction: useful in impact analyses. Finally, because the one land use variable (total land) had been ineffective and difficult to calibrate, we replaced it with one measuring employment density in each zone—a proxy for land or rental prices.

The original DRAM attractiveness index included four socio-economic variables (percentages of each household income group), and three land use variables, all lagged in the two time-period calibration. One of the land use variables (amount of vacant land) had been dropped.
due to collinearity problems. What was left were the residential land acreage and the percent of developable land developed, which of course included the effect of vacant land. Work with the model indicated deficiencies both in "handles" through which to analyze land use policy changes and also in the dynamics of the model for very long-term forecasting and simulation, particularly regarding evolution of local land markets.

Consequently, a couple of additional land use variables were added for DRAM85. One is the percentage of households in a zone that occupy multi-family units, intended to represent relative residential density in the zone. This variable was feasible only after development and inclusion of a single-/multi-family household submodel in DRAM85, described below. It was included in order to introduce explicitly the land use density in terms familiar in land use plans.

The other new variable is a generalized accessibility variable—accessibility both to all employment locations in the region and to all household locations as well. The variable was designed and calibrated with parameters to approximate a land rent surface for the region in actual magnitude. In the DRAM85 forecasting model it was intended to operate dynamically over long time periods to simulate land price rises in zones as general accessibility and zonal development progressed, and with no "ceiling" as with the development or multi-family percentage variables. For purposes of calibrating with these three land use variables, however, it was necessary to combine them into a single zonal land index with a single estimated parameter, a specification which still retains the effects of all three variables.

Composite Cost Travel Impedance

Another change has involved less the structure of the models than the definition and measurement of one of the key variables. Almost all previous versions and applications of DRAM had used zone-to-zone highway times as the measure of impedance to travel from residence zone to workplace zone, or from residence to shopping. Despite a strong demonstrated correlation between highway times and overall costs of auto commuting, and although the highway time measure had calibrated reasonably well in previous applications of DRAM, there were practical shortcomings for purposes of forecasting and simulation. These included: (1) accuracy and credibility in forecasting simply because of the omission of transit in a region with a significant work-trip transit ridership, and (2) difficulties in simulating alternatives on transit and traffic control measures at the trip attraction end, such as transit fares and times, and auto parking costs.

These problems had been handled with other models in other regions in at least two different ways. One was a simple combination of highway and transit times. Another was to split workers into auto and transit modes before allocation to residential zones. Neither, however, considered the multiple elements of travel costs affecting trip-making behavior and residential choice.

Instead, we developed a composite cost travel impedance measure, based on a prototype for the New Orleans region trip distribution model (Allen 1984). This procedure adapts the total impedance measure in the denominator of the multinomial logit-mode choice models in wide use in regional transportation planning agencies. These denominators are a measure of the total disutility of travel by all modes between each zone pair for each household type—a measure composed of several elements pertaining to zone-to-zone travel costs, such as auto time, operating costs, parking costs, and transit-run time, wait/transfer time, and fares. With aggregation and scaling, this measure, as calibrated for the region, could be used as a composite cost travel impedance for trip distribution and urban activity models. An additional advantage in the Puget Sound region is that this impedance is similar to one developed earlier for zonal links served exclusively by auto and passenger ferries, thus bringing a consistent measure to all zones.

This composite cost impedance was thoroughly tested with the trip distribution model for trip length frequencies and zone-to-zone work trips (in comparison with observed values). When DRAM85 was calibrated with it, the overall fit was at least as good as with the peak highway times. However, the
Composite cost impedance did not fit well in calibrations of EMPAL85. Since the theory of travel impedance and the location of employment with respect to households is much looser than for residential location, and the use and cost of transit probably much less relevant, the EMPAL85 model was calibrated with highway times.

**DRAM Submodels**

Another type of modification to the DRAM model was the addition of two submodels, one predicting the single/multi-family distribution of households, the other the residential land consumption of households. At the PSCOG, the SF/MF distribution had already been predicted from future year household forecasts through a single-equation multiple regression model whose parameters were estimated on 1970 and 1980 data. This model had provided good predictions (given the household forecasts), but it became desirable to bring the model within the DRAM85 model as both an input and an output. (The percent multi-family households in a zone was one of the new attractiveness variables.)

At the core of the SF/MF submodel in DRAM85 is a multiple regression equation predicting the number of single-family households in each zone. It was specified so that future year predictions of all explanatory variables would be endogenous to the DRAM85/EMPAL85 system. It was also specified such that the zonal fraction of single-family households would be at least partially dependent on the regional single-family trend, which is predicted through the PSCOG regional econometric model. In recognition of the permanence of structures, the strongest explanatory variable is the percent single-family in the previous time period. Then changes between periods are explained by changes in household composition in the zone, the rate of total household change, the degree to which the zone is developed, and special circumstances of municipal land use policies.

The residential land consumption submodel is similar to the SF/MF submodel. In earlier versions of DRAM, the amount of residential land per household would be exactly the same as existed in the base year, as long as vacant developable land could be consumed at the same rate. Densities could increase only after full development. Following tests by Putman and his associates, we developed an improved residential land consumption procedure for DRAM85 that allows residential densities to increase continuously. Once again, the core is a multiple regression equation specified so that future values for all explanatory variables would be endogenous to the DRAM85/EMPAL85 system.

Again, the most important explanatory variable is the residential land per household in the previous time period. Changes between periods are explained by the rate of housing growth, the type of housing, and the degree of development in the zone. The advantages of this new submodel procedure are that over a long-term forecasting period the marginal consumption of residential land will adjust continuously to increasingly full development in a zone, and that the rate of land consumption will be flexible in response to simulation of policy and development impacts.

Several other nonstructural adaptations have also been made to the DRAM85 model. One example is developing a procedure for predicting the future year average persons per household in each zone from the average in the base year and the change in the regional average between periods (which is predicted through the PSCOG regional econometric model). And a number of output-reporting enhancements have been made using SAS software, especially in the aggregation of zones and display and analysis of output variable changes over time periods.

Those interested in the detailed specification of DRAM85 and EMPAL85 are referred to the technical documentation report (Watterson 1986) available from the PSCOG.

**Calibration of DRAM85 and EMPAL85**

At the PSCOG, the central Puget Sound region (consisting of four counties and about 2.7 million population in 1990) is divided into 161 forecast and analysis zones (152 in the modelable urbanized area). Households are disaggregated into the usual income quartiles, and employment (defined as total jobs, including part-time, self-employed, and military) is broken into five general industry
sector groupings. The two-period calibration used zonal data from 1970 as the base year and 1980 as the prediction year. Zonal data on households are drawn from the U.S. Census; employment and land use data are normally from special surveys or estimates. Zone-to-zone travel impedances are derived from urban travel models, in particular, mode choice and network assignment models.

Parameters for DRAM85 and EMPAL85 were estimated with the special calibration program, written by Stephen Putman, which uses an iterative gradient search routine to find parameter values best fitting the calibration data. The program produces summary statistics on the goodness of fit, but not statistics on the individual parameters. The summary statistics presented here are:

\[ R^2: \text{ the coefficient of determination from a regression of actual zonal values on estimated values.} \]
\[ C: \text{ the calibration criterion value.} \]
\[ B/W: \text{ the best-worst achievement ratio, a measure of the extent to which the best-fit parameters are an improvement over the uniform distribution.} \]

The rest of this section describes the 1985 parameter estimates and the summary statistics for each equation.

For EMPAL85, the calibration consisted of estimating 1980 employment in each of the five industry sectors from 1970 employment by industry, 1970 households, 1970 land use, and 1980 highway travel impedance. The parameter values obtained from this calibration are shown in Table 1. It should be noted that the parameters can be compared relatively across industry sectors being calibrated, but that within any equation the magnitudes of the values on the variables can differ widely, thus affecting the parameter estimates. Similarly, the best comparative summary statistic is the B/W ratio, which is invariant to the equation being estimated.

Virtually all of the parameter estimates have the expected sign, though some of the inter-industry effects are small and the direction of the relationship is debatable. The \( a \) parameter estimates are all negative, with the one in the retail trade equation the largest, which was expected because of the connection between that industry and household markets. Manufacturing has the next largest parameter value, but that may be affected by the dominance of Boeing plants in the manufacturing sector. Services and wholesale trade had lower parameter estimates on the travel impedance to households, but they had the largest of the estimates on the \( p \) parameter, which relates the sector employment to all other employment locations. This indicates a business orientation of these sectors, compared with retail trade, government, or manufacturing. All of the \( p \) parameter estimates were positive. Of the inter-industry attractions, government shows no relationship with any other sector, and the same with retail trade. The manufacturing

<table>
<thead>
<tr>
<th>TABLE 1. EMPAL85 Calibration Results</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Industry Sectors</strong></td>
</tr>
<tr>
<td>Parameter</td>
</tr>
<tr>
<td>a</td>
</tr>
<tr>
<td>e1</td>
</tr>
<tr>
<td>e2</td>
</tr>
<tr>
<td>e3</td>
</tr>
<tr>
<td>e4</td>
</tr>
<tr>
<td>e5</td>
</tr>
<tr>
<td>p</td>
</tr>
</tbody>
</table>

The goodness of fit statistics were:

\[ R^2: .935 \]
\[ C: -30282 \]
\[ B/W: .9716 \]

The parameters listed above were on the following variables:

- a: the travel impedance function
- e1: the lag of the manufacturing employment
- e2: the lag of the W.T.C.U. employment
- e3: the lag of the retail trade employment
- e4: the lag of the services employment
- e5: the lag of the government/education employment
- c: the lag of the employment land per employee
- p: the lag of the proximity to employment in all zones
TABLE 2.
DRAM85 Calibration Results

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Lower Income</th>
<th>Lower Mid Income</th>
<th>Upper Mid Income</th>
<th>Upper Income</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>-1.9186</td>
<td>-1.6599</td>
<td>-1.3921</td>
<td>-1.4898</td>
</tr>
<tr>
<td>b1</td>
<td>4.8402</td>
<td>1.8998</td>
<td>1.0532</td>
<td>-0.4344</td>
</tr>
<tr>
<td>b2</td>
<td>1.0322</td>
<td>2.9524</td>
<td>1.0322</td>
<td>0.3342</td>
</tr>
<tr>
<td>b3</td>
<td>-0.6337</td>
<td>0.0520</td>
<td>3.8521</td>
<td>1.9929</td>
</tr>
<tr>
<td>b4</td>
<td>-0.4247</td>
<td>-0.1021</td>
<td>0.1455</td>
<td>3.0712</td>
</tr>
<tr>
<td>s</td>
<td>0.6556</td>
<td>0.7031</td>
<td>0.7815</td>
<td>0.7726</td>
</tr>
<tr>
<td>u</td>
<td>0.9120</td>
<td>0.5406</td>
<td>-0.1439</td>
<td>-0.2817</td>
</tr>
</tbody>
</table>

The goodness of fit statistics were:

- \( R^2 \) .827 .843 .849 .871
- C -13049 -9106 -7000 -7809
- B/W .9873 .9912 .9932 .9924

The parameters listed above were on the following variables:
- \( a \): the composite cost travel impedance function
- \( b_1 \): the lag of the percent lower income households
- \( b_2 \): the lag of the percent lower-mid income households
- \( b_3 \): the lag of the percent upper-mid income households
- \( b_4 \): the lag of the percent upper income households
- \( s \): the lag of the amount of land in residential uses
- \( u \): the composite land index

parameter on services location is negative, and W.T.C.U. has a positive parameter on retail trade and negative on services. Finally, the employment density parameter was negative in all equations, and more negative for the land extensive industries of manufacturing and wholesale trade, which need locations with lower land rents than the services sector.

The calibration of DRAM85 consisted of estimating 1980 households in each of four income quartiles from 1980 employment, 1970 households by income group, 1970 land use, and 1980 travel impedance. The parameter values obtained from this calibration are shown in Table 2.

Again it should be noted that the parameters can be compared relatively flat across income groups, perhaps because of the composite cost travel impedance. In general, the parameter estimates on the lags of the household income group percentages were highest on the same-group, and otherwise following a like-seeking-like pattern. All of the residential land parameter estimates were positive and of almost the same magnitude. Finally, the estimates on the \( u \) parameter for the composite land index were highly positive for the lower income group and declined with higher income until moderately negative for the upper income households. This result was expected, since lower income households would have a tendency to locate in the older, denser, more developed zones, and to consume less housing and land there, while the higher income households would generally be expected to be negatively attracted by such zones.

Any meaningful prediction tests of calibrated models would have to be outside of the 1970-1980 calibration periods, but because of the ten-year periods, no observed zonal data exist beyond 1980. So, to this point, no real prediction tests with the DRAM85 and EMPAL85 models as calibrated have been conducted.

Forecasting and Simulation
Experience with DRAM and EMPAL

The DRAM and EMPAL urban models, in their various versions, have been applied to several different project purposes at the PSCOG. The original purposes for which they were to
replace EMPIRIC were for:
(1) long-range small-area population and employment forecasts, and (2) "land use" inputs to trip generation and mode split models. Other applications have emerged in the last few years, including (3) impact analysis on transit development and public-facility siting alternatives, and (4) simulation analysis in iteration with the standard UTPS (Urban Transportation Planning System) travel demand models. Some of this applied experience is discussed below in this section.

Population and Employment Forecasting

At the PSCOG, small-area forecasts of population and employment are prepared about every two years, with a usual horizon of fifteen to twenty years. Since back in the 1960s, urban activity models have become an integral part of the process of allocating regional population and employment totals to forecast zones. A substantial constituency for these forecasts has developed over the years, including PSCOG-member local government staffs; other local, regional, and state agencies; non-profit institutions; retail and other businesses; real estate developers and consultants; and others. The forecasts once prepared by staff are subjected to an intensive review, sometimes on a zone-by-zone basis, before being adopted by the PSCOG board for use in planning work.

A certain mystique has grown up around the use of models for developing the forecasts, as if this invests them somehow with greater accuracy or insight. Absurd as it may be, this still is one valid reason for the continued use of models in forecasting, at least in the Puget Sound region. But there are technical reasons as well. While population and employment forecast totals could be allocated to small zones just as "accurately" by manual or delphi methods, models like DRAM and EMPAL offer considerable advantages in doing so. For one thing, internal consistency is a lot easier to maintain in the forecasts. Zone totals will always add up to the regional total, population and households will have the desired relationship, and so forth. Anyone who has tried to do this manually can attest to its difficulty. And the forecasts will bear some relationship to expectations on urban development, in other words, a theoretical model. New growth of certain household types or employment sectors will tend to follow some accessibility or socioeconomic patterns. This is difficult to effect by hand, but it is what models are all about.

Finally, there is the sheer volume of zones and data, which a programmed model can put into manageable form, though any programming could do as well.

In sum, the advantages of models are as useful and sophisticated tools in the population and employment forecasting process. They are not black boxes which magically produce better forecasts than by other means. In forecasting with models, as in forecasting by any method, there can be no substitute for human technical expertise.

Inputs to Travel Demand Models

The other traditional use for outputs of activity models at the PSCOG has been as forecast inputs to the travel demand models, particularly the trip generation and mode choice models. The PSCOG has a well-developed capability with the UTPS program package, which has been progressively tailored to the extensive travel forecasting needs of the agency. It is this purpose for activity models that has in fact justified and funded much of the development work on the models over the years.

The trip generation model (a set of multiple regression equations) and the mode choice model (a set of multinomial logit equations) require zonal level forecast-year inputs of households by income group, total population, and employment by industry sector. These can be and are provided through the use of the DRAM and EMPAL models (after disaggregation to traffic zones through a mechanical routine). The actual outputs of DRAM and EMPAL have been designed to fit these needs, in terms of zonal configuration, forecast years, industry sector groupings, and so forth. For example, the original simplification of zones and models outputs when implementing DRAM and EMPAL in 1981, with only 90 zones and four industry sector groupings, turned out to be inadequate for trip generation purposes and were revised in 1983. The zone structure is to be revised again in conjunction with the 1990 census.

Even so, the DRAM and EMPAL models produced insuffi-
cient forecast inputs for trip generation, fewer than did EMPIRIC, to which the trip generation equations originally had been tailored. DRAM did not produce a household-by-size distribution (average household size only) or a single/multi-family household forecast, and everything allocated to far fewer zones. As indicated, a single/multi-family submodel has been added subsequently. And more modifications will be made in the future to meet trip-generation input needs. There is no inherent reason why DRAM and EMPAL cannot be further adapted to meet all travel demand model requirements. But my summary judgment right now is that DRAM and EMPAL as applied at the PSCOG do not fulfill this function quite as well as did EMPIRIC.

Impact Analysis

The more flexible and less costly attributes of the DRAM/EMPAL model system have led to more applications for purposes of impact analysis. There would probably have been more to this point if the PSCOG project staff and planners in the region had been more accustomed to this use of models and consequently had asked for this type of analysis more often. But this is slowly changing. The challenges of planning for growth in the late 1980s have led to several applications of the models for systematic analysis of alternative policies for transportation investments and growth management. One of these is briefly described in the section on iteration with travel models. Most of the impact analysis below was with an earlier version of the models, DRAM83 and EMPAL83.

One application of the models was in evaluating the regional land use impacts of several transit development alternatives for the Puget Sound region, including an advanced technology bus and a light rail system. The analysis was to be conducted in comparison with base forecasts for a horizon year of 2000. The only variable that would change between alternatives would be the travel impedance, with the objective of estimating the locational effects of the different alternative transit proposals. Since this analysis was prior to development of the composite cost impedance measure, the travel impedance was taken from highway skims manually adjusted for transit-travel time savings and mode split. The analysis was further complicated by the fact of the bus alternative being redefined to cover all three major corridors to the Seattle CBD, while the light rail alternative at that time included only one corridor.

Nevertheless, the results of the analysis were reasonable and informative on the question of impacts. There was a fairly substantial positive impact on job levels in the Seattle CBD and adjacent areas, and negative on suburban areas, of both types of transit alternatives. Residential impacts were not as great, and not as significant as would have been expected from these alternative investments. One reason could have been the extensive park-and-ride provisions in the transit alternatives. But the alternatives themselves could be defined only in terms of a relatively few minutes of commuting time saved, and only for the transit mode riders. These inputs were drawn from the travel forecasts, which had in turn been based on a baseline set of land use forecasts. These deficiencies in this analysis argue for use of the composite costs impedance measure and some sort of iteration between urban activity and travel demand models. For more detail on this impact analysis, see Watterson (1985).

Another type of analysis was of the household and employment impacts of a proposed Navy base in the Everett area of the Puget Sound region. In this project, the regional impacts (direct and indirect) were first estimated with the PSCOG regional econometric model, then both the direct and total impacts were to be (separately) allocated to zones with the DRAM and EMPAL models, under two different assumptions of contractor job levels, all for both 1990 and 2000. As can be imagined, these dimensions involved an enormous volume of numbers, which at best would be very difficult to allocate without use of models. In fact, some consultants for the Navy attempted to do so, and were quite unsuccessful in producing full or reasonable results. DRAM83 and EMPAL83 were used in the original PSCOG analysis project (Shindler and Watterson 1984), and a later follow-up used DRAM85 and EMPAL85 (Watterson 1987).

In our use of DRAM83 and EMPAL 83 for the analysis,
we did succeed in producing overall good results, but the process showed some important flaws in the models, some of which were at least partly rectified in DRAM85 and EMPAL85. One problem was in generating any type of support employment that would surely develop in the vicinity of a new Navy base of 8,600 military and civilian personnel. This resulted from the weak or nonexistent interaction among industry sectors in the same or adjacent zones in the EMPAL model, now corrected.

A more intractable problem was the scattering of Navy personnel and indirect impact household residential locations all over the entire Puget Sound region. This problem stems from the combination in DRAM of both a gravity type travel impedance function and a zone attractiveness function determining the residential locations. The impedance may not be relatively strong enough to confine the household allocation to a feasible perimeter, without direct, clumsy intervention by constraining zone totals. Of course, one can argue that households do in fact locate all over a metropolitan region, but at least in this analysis case this was not an acceptable result.

**Iteration with Travel Demand Models**

A final category of model uses at the PSCOG is less a self-contained application than an approach to doing forecasting and impact analyses. Most modellers recognize that population and employment (or land use) distributions are both direct inputs to travel demand models, and are in turn directly affected by travel demand, as in vehicle assignments on highways or disutility of travel. But few land use or transportation analysts have attempted to integrate the two types of modelling as this would indicate doing. Actually, DRAM has some capability to bridge the gap with a simplified trip generation and distribution. Putman (1983) has been a pioneer in applying DRAM iteratively with an assignment model, both in research and consulting contexts. Transportation analysis in practice is moving slowly in this direction, and we at the PSCOG have made some progress as well.

In one study, future land use impacts of eight different alternatives for ferry service on Puget Sound were estimated with DRAM and EMPAL, using impedance inputs from the travel demand models. Then the implications of the ridership volumes for the ferry system were evaluated by distributing the cross-sound trips and analyzing financial and service impacts. The travel impedance used was a newly developed composite cost impedance measure, including run, loading, wait times and ferry tolls, calibrated to observed ferry ridership. The land use impact results were very good, especially considering the rather small variations in impedance among alternatives. The results were good enough to make inroads toward conversion of some remaining model skeptics on the agency staff. Much of this analysis is described in a report (Dinndorf, Shindler and Wattersen 1985) available from the PSCOG.

Another application of iterative procedures was in extending population and employment forecasts beyond 2000 to the year 2020, as input to travel forecasts for a transit development study. No baseline travel forecasts previously existed for 2020, so that no highway skims (or composite impedance) could be derived as input to the DRAM and EMPAL models. Consequently, a year 2000 highway impedance was used with DRAM83 and EMPAL83 to make initial population and employment projections for 2020. These then could be used to generate and distribute trips and, with some assumptions, split trips by modes and make assignments for 2020, which with only modest highway-supply improvements between 2000 and 2020 brought some significant congestion on major corridors, and much lower speeds. The zonal impedances from this assignment were then input into DRAM83 and EMPAL83 for another iteration. The results from this second pass were excellent. The congestion dramatically lowered the Seattle CBD employment and increased it in suburban counties. Growing residential suburbs levelled off as they approached capacity after 2000 and growth continued in exurban areas. In short, the models were very sensitive to network input changes, and they performed well in modelling the very long-term development of the region.

More recently, DRAM85 and EMPAL85 were used with the UTPS travel models to analyze land use and travel de-
mand impacts of several long-range development alternatives for the Puget Sound region. Alternatives included both concentrated and dispersed employment, and different packages of highway and transit facility investments. The approach was to use DRAM85 and EMPAL85 iteratively with UTPS travel models in at least two complete cycles to evaluate impacts relative to a baseline. Composite cost impedance was used in DRAM85. The results overall were good. For the alternatives involving land use, there were reasonable, but not large, effects on employment, but weak impacts on household locations. For the transportation investment alternatives, there were strong impacts on households and weak effects on employment. Again, the models were clearly sensitive to network changes, but not nearly so much so with respect to changes in work locations. These results are indicating either a reality of relatively invariant work-trip-length frequencies, or else a particular weakness in the models for this type of simulation.

Future Directions

A few final words are warranted concerning the future of DRAM and EMPAL, and of urban modelling in general, at the PSCOG. This is an era of vastly lower funding for planning activities, and also one of change for transportation modelling and computer applications. It is also a period of ferment for regional planning agencies, the MPOs that have been at the forefront of applied modelling, forecasting, and analysis.

At the PSCOG, the future holds at least some continuation of the directions already established of adapting the DRAM and EMPAL model system constituency. Major structural changes are probably finished, but additional variables are possible, and there will likely be new submodels, better specifications of key relationships like household size, workers per household, part-time and off-peak workers, and some bells and whistles calculating specific desired outputs. We would like to try DRAM and EMPAL for micro-zone modelling of land use and transportation policies in defined suburban areas—a regional model system with some small area grain. And, in any event, there will be a new calibration to 1990 census data (when available), and perhaps some comparative analysis of 1980-90 parameter estimates with those from 1970-80. In short, we feel committed at least for now to urban models, to DRAM and EMPAL, and to continued modification of the models to serve our needs better.

At the same time, further integration of DRAM and EMPAL with the travel demand models has become an even higher priority. Not only will we be developing more efficient procedures for input and output between the model systems (such as expanding or collapsing zone structures), but we will also be experimenting once again with shortcuts in the chain, such as the use of DRAM for trip generation and distribution, and more flexible mode split and assignment models. Most important, the attitudes both inside and outside the agency are quite supportive of the need for even better iteration between the land use and travel demand models; it has not always been so.

In the fast-changing world of computers and their applications, especially in the direction of microcomputers, one cannot overlook the problem of user-friendliness of the models and the potential for expanding the range of model users. While these certainly are technically feasible, with some programming work in creating advanced input and output procedures, I remain somewhat skeptical about the potentials here. In the early 1980s, the U.S. Department of Transportation adapted a version of DRAM and EMPAL for inclusion in its UTPS model package, thereby making them more available to many more users. But these are for the most part experienced modellers who had previously ignored land use inputs. I find a high premium on modelling experience and judgment and an empirical "feel" in successfully using models for forecasting and especially for analysis. From observation in the Puget Sound region, I am doubtful that sufficient expertise (or interest in developing it) now exists among potential users in local government staffs. And maybe it never will, since after all there were some efficiency reasons for centralizing modelling in the first place. In other words, success in modelling is fundamentally dependent on human expertise, not on the models themselves.
Finally, there is the matter of financial resources and the organizational context for models. DRAM and EMPAL were applied and developed at the PSCOG on something like a shoestring. They, unlike their predecessor EMPIRIC (and their cousins the UTPS models), or even other applications of DRAM and EMPAL (such as in the Los Angeles region), were not dependent on large-scale federal or other funding. They can continue to prosper under low-funding conditions. At the PSCOG, models, both urban activity and travel demand, have become more integrated, more visible, and more tied to local planning and funding. This could expand the role played by such models and analysis in local planning and ensure the future funding available for the program. Much of this would be oriented to applications, seeking to be more useful and more relevant to more local activities.

Maybe one should be somewhat skeptical about this direction as well, because, in the world of models, forecasts, and databases, everyone talks a great game but few seem to play for pay. Just what sort of regional program can be supported with mostly local priorities and funding remains conjecture at this point.

References


FEATURES

Statement of Editorial Intent

Information, lightly or seriously treated, presented in many styles and formats, responding to your diverse interests—that is our intent.

We provide you an opportunity to enjoy information. And an equal opportunity to share information with others. In this section of the Journal you can communicate ideas, impressions, perspectives to colleagues you know and those whom you have not yet met.

Topics mirroring the diversity of our readership, reflecting your (and their) diversity of needs, activities, places and personages. Blending information with the art and science of communication. These are our goals.

Please contribute.

John C. Antenucci
Gilbert H. Castle, III

Note: Jodi Kilcup, a staff writer at PlanGraphics, Inc., is a contributing editor to this section.
An Earth Day Lament
Alan Robinette

Earth Day, April 22, 1970, was, to me and many of my colleagues, an injection of spirit and commitment toward a better-planned environment. Earth Day established new ideals and inspired a ground swell of support for the environmental movement. I interpreted Earth Day as a commitment to better understand, describe, and respond to environmental processes. To me, it was the starting signal for a long journey.

I prepared myself with six years in architecture school and three years in landscape architecture graduate school. I applied Ian McHarg’s theories of “ecological determinism” to school projects. I worked in the Philadelphia office of Wallace, McHarg, Roberts, and Todd on an ecological inventory of the Twin Cities and then applied the inventory to land-use planning decisions while working for the Metropolitan Council of the Twin Cities. In addition, I taught regional design and land analysis classes at the University of Minnesota Department of Landscape Architecture. I established a nonprofit office, named Enviromedia, Inc., to conduct research and environmental studies.

It seemed to me that it was all coming together. Before Earth Day, environmental modeling concepts, methods, and case studies were demonstrated, but no one seemed to need them.

After Earth Day, the demand to deal with newly recognized environmental and urban growth issues suddenly expanded beyond our ability to deliver. Passage of the National Environmental Protection Act (NEPA) accelerated modeling activities. NEPA required environmental impact statements on the ecological, economic, and social impact of development decisions. Studies such as “Limits to Growth” by the Club of Rome set the tone for a holistic approach to global management. The journey had begun.

Idealistic ’70s

GIS (geographic information systems) had its beginnings with a set of environmental ideals. Though computer mapping technology was rudimentary, the modeling theory was robust, even by today’s standards. The approach of many early GIS studies was comprehensive. We attempted to model environmental systems such as erosion and runoff, aquifer recharge, wildlife habitat, and many other critical environmental processes. We attempted to distinguish between land-use capability and suitability in the siting of new activities. Methods were used to optimize the use of a site through iterative cycles of land-use allocation. We attempted to translate public values into resource-based maps. We took a rigorous approach that developed quantitative measurements for such terms as carrying capacity, sustained yield, and impact tolerance.

We operated under a number of unwritten assumptions. First, and foremost, we admitted that insufficient knowledge existed to adequately model the environment. We believed that it was more important to be exhaustive in breadth than in depth, and that successive studies would continue to refine the reliability of our models. We acknowledged that comprehensive models required the involvement of specialists from many disciplines and we saw that our task, as generalists, was to mobilize resources and to expedite that collaboration. We recognized GIS could be the great integration tool to rally interdisciplinary judgments. As designers, we even hoped GIS could assist the plan-making process by allocating the right amount of activity, in the proper location, and with the proper juxtaposition. In retrospect, our dreams far outdistanced our knowledge and tools; we were a bit like soldiers sent into modern warfare with spears.
Comprehensive Case Studies

Heightened client demand coupled with enhanced professional confidence resulted in a number of contract studies. These projects incorporated a probing, problem-solving style when clients were not sure what they expected and the consultant wasn’t quite sure what could be produced. In many cases, the work plan was developed on the fly. The target was always known, but the approach and techniques were in constant development. The following two studies were landmark cases that supported the early environmental ideals and elevated the “state of the practice.”

The “Natural Resource Protection Study” was conducted for the Metropolitan Council of the Twin Cities (Einsweiler) by Enviromedia, Inc. (Robinette, Wessel, Kline, Kivens, Callaway), and Steinitz Rogers Associates (Steinitz, Murray, Rogers, Sinton, Toth, and Way), in 1971. This study responded to an airport zoning act that gave regional government authority to regulate future land use within five miles of a new airport. Based on environmental protection strategies, two alternate airport sites were evaluated. 20 critical site systems were defined
and modeled, and impact assessments were performed for eight land-use intensity types. Regulations were developed based on impact tolerance. Hypothetical plans were generated and evaluated.

"Muscatacutuck National Wildlife Refuge Plan" was conducted for the U.S. Fish and Wildlife Service (FWS)/Crozier) by the Department of Landscape Architecture, University of Minnesota (Robinette), in 1973. This project applied the Objective Setting Process developed by the FWS. Their process established values (resource benefit units) to all 45 potential activities for the refuge. The models identified potential sites, measured maximum capacity, developed tradeoff strategies for conflicting uses, and prepared a plan with optimum capacity. This combination of resource values, GIS, and models allowed for the development of a defensible plan.

These projects relied on concepts and methodologies from slightly earlier studies. DELMARVA, a 1967 land-use study of the Delaware-Maryland-Virginia peninsula, was prepared by the Department of Landscape Architecture at Harvard University (Steinitz), using the raster mapping package, GRID. A state pilot study was conducted for the New York Land Use and Natural Resource (LUNR) inventory program by Cornell University (Belcher et al.) and Harvard University (Steinitz et al.), in 1968. The Blackbear State Forest and Sunrise State Park was studied for the Minnesota State Planning Agency (Williams) by the University of Minnesota Department of Landscape Architecture (Robinette), in 1972.

when Version 1 of the mapping package Environmental Planning Programming Language (EPPL) was developed. Each of these early projects all employed comprehensive planning approaches and selectively applied views of analysis, input-output modeling, and plan organization algorithms.

These studies were comprehensive in scope, although they may have been tentative in depth. Their approaches strongly contrasted with the intuitive design methods commonly used then. These pioneering studies demanded the quantification of site requirements and impact measures. They resulted in tangible plans derived from conceptual ideas and abstract relationships. Although the outputs from these models were "line printer" maps presented with an apology, the study results were understandable and defensible.

Problems Arise

Over the past 20 years, there has been a dramatic evolution of GIS. The mainframes of the '70s have been replaced by the desktops of the '90s. Software, data, and graphics have improved substantially. However, to what degree has modeling also evolved over the years? How have we collectively applied our energy and knowledge toward a better planned environment using GIS models? How many impact studies have used GIS predictive models?

There are, in fact, surprisingly few sophisticated models in practice today. Instead, most applications are simple, descriptive maps illustrating thematic characteristics of resource inventories. A few applications use static, overlay analysis describing suitability or vulnerability. There are very few applications that utilize dynamic simulation techniques that more realistically describe the environment. After 20 years, are we still in the infancy of the GIS modeling field? Why is this? What forces have kept us from advancing at a more rapid rate?

The reason for this aborted evolution and possible retrenchment in the development of models is multifaceted and complex. I have struggled to diagnose the problem, and these are what I see as some contributing factors behind the barriers to modeling:

- Most of us tend to believe that other people are like ourselves, have similar values, and share common thought processes. One measure used by psychologists to differentiate the way that people perceive and judge is the Myers-Briggs Type Indicator preference test. The test ranks people on a polar scale from "sensory" to "intuitive." A purely sensory person finds out through eyes and ears what is reality. A purely intuitive person seeks out meanings, relationships, and possibilities that are beyond one's senses. Three sensory people exist for each intuitive person. Sensory people are more satisfied with evidence that is practical, observable, and factual. They are less comfortable with ideas, projections, and problem-solving. At its worst, this is a myopic view that accepts only what can be demonstrated in the present tense.

There is a distinct mistrust of the results of predictive models.
by many scientists, decision-makers, and laypersons. The planner's goal is to construct defensible arguments about the future by applying the best available data and models. The question is what degree of exactness, or what range of tolerance for approximation, is required for an acceptable model? What mechanisms can be used to gain the acceptance of sensory types?

Since I am an intuitive type, I find satisfaction in modeling the future. I am tolerant when the model results deviate from apparent reality and I can accept a large degree of uncertainty in my understanding of environmental processes. But the vast majority of people have trouble with such a conceptual framework. They do not initiate models and may resist others who rely on them. Can this explain some of the dampening effect on GIS modeling?

- There are a number of fixations associated with the GIS field—fixations with technology, data, and organizational structure. The technology fixation focuses on computer hardware, vectors, topology, command structure, graphics devices, and standards of all kinds. The data fixation emphasizes accuracy, resolution, classification, conversion, format, and exchange. Organizational fixations give priorities to institutional structure, "getting started with a GIS," surveys of GIS activities, and personnel issues. It's not that these topics are unimportant; they should, however, be viewed as a means, not an end. My concern is that applications are not viewed by many as the final, and only true, objective of a GIS. To what degree do these exaggerated preoccupations with technology, data, and organizational structure detract from the decision-support objectives of GIS?
- Bureaucracy's incessant need to compartmentalize its work and fragment issues into the organization's functions has stifled the development of holistic models. GIS projects and applications have been narrow in scope because they have been authored by individuals in support of single purposes. The interdisciplinary knowledge necessary to model the environment must come from varied specialists. Such cooperation is rare in university, agency, or consultant settings. The development of common GIS databases is one area where this cooperation has evolved. It is hard to understand why the same cooperation is not fostered in an effort to develop better models. Is it simply that people have not yet confronted the modeling step in their GIS development? Have organizations not incorporated pilot studies and prototyping methodologies in their GIS strategies? Have the generalist planners failed to provide adequate leadership? How will GIS staff respond when an enlightened public official does request a computer simulation of a proposed action?

I hope it is not necessary to change the way people perceive or to alter the organization of bureaucracies in order for GIS to flourish. However, it will be necessary to resist the constraints of myopia, fixation, and fragmentation for GIS to realize its full potential.

To the Future

As Earth Day 1990 has come and gone, it is time to renew our original spirit and commitment toward a better-planned environment. This time, GIS has a battalion of users rather than the cadre it had in 1970. Although there are more GIS installations, more GIS data, and more GIS staff, this does not guarantee more and better GIS applications. The future will require all of us to redirect emphasis away from our fixations and toward results. We should focus on ends rather than means. Perhaps the advent of the term "expert systems" will lend a new legitimacy to the analytic models written since the '70s. Maybe the arrival of simulation games such as SimCity (Maxis) will spur other people to explore and model new complex relationships. I hope that on future anniversaries of Earth Day we can celebrate the accomplishments of planning for the environment through GIS models.

Alan Robinette is director of Minnesota's Land Management Information Center, State Planning Agency, a service bureau with an annual client revenue of $1 million that offers GIS products and services to other government agencies.
It is now commonplace to lament the information explosion—the ever-expanding surge in papers, newsletters, junk mail, consultant studies, computer printout. Like their counterparts throughout industrial society, local government "knowledge workers" are increasingly challenged to assemble, filter, evaluate, search, and present information. How can this process be made more productive? In other words, how can local government better cope with the information age?

One of the new information concepts that promises some help is hypermedia. Also known as interactive multimedia, this is an approach that uses the computer to store and retrieve information in many separate formats—texts, numbers, sounds, and images. Moreover, the combination and sequence of information that is presented is tailored directly in response to the user's most recent assertion or query.

Consider the typical book. Most of us read it in a sequential fashion, front to back, chapter to chapter, paragraph to paragraph. In most cases, understanding the later pages requires having read the earlier pages; hence, it can be considered a linear medium. There are, of course, features designed to assist the direct search, as opposed to linear processing of information; the table of contents and index both help the reader to go directly to a segment of information. Footnotes provide guidance to related information, as does the bibliography.

Hypermedia, and its subset hypertext, emphasize features that allow the direct search and retrieval of information, working in a non-sequential as opposed to linear manner. The typical hypertext or hypermedia system is structured to facilitate the transition from one segment of information (usually referred to as a node) to another. The user can create his or her own branches through the information base, as well as follow the paths suggested by others.

The St. Louis Example

The St. Louis Riverfront Planning and Design System is one of the first hypermedia systems developed for a city. Planners and other city officials concerned with the 19-mile riverfront have access to a rich array of facts and opinions about the Mississippi and adjacent shore—its characteristics, problems, and opportunities. Sitting in front of the two-monitor system, one can:

- Navigate up or down the river, viewing images taken from a helicopter, boat, or at ground level. Stop at an area of interest and the computer will list those subjects for which it has information. A computer map indicates where the viewer is situated.
- Examine images of a location from many perspectives—the oblique aerial view as seen from the west, north, south, or east; a conventional aerial photograph; the site on an USGS map; and more.
- Request all there is to know about a given subject such as businesses along the riverfront, or about a particular location. For example, what have previous plans said about a particular site?
- Prepare a report that combines text from specific cards with selected video images, all edited into an appropriate report format that is suitable to the occasion.
- Designate a site of interest on the video or map by using a computer sketching or painting tool. This highlighted image could then be built into a computer-based presentation.
- Demonstrate how a landscaping or building improvement would look by converting the video image to a digital format and then altering it. This is the modern equivalent of an architect's rendering of a potential project.

Funded by a National Endowment for the Arts Design with Cities grant, and matched by the city of St. Louis, the hypermedia system uses readily available and affordable equipment. A microcomputer (Macintosh IIcx) runs the software and stores the nodes of information. These are kept in "cards" using a software package called Supercard published by Silicon
and development funds into the software and hardware that will support interactive multimedia during the '90s.

What could it mean for state and local governments? Most observers detect four application categories with potential:

Point of Information

The 1989 URISA Conference in Boston provided some good hints of future multimedia applications. Ed Crane (M. J. Harden) and Marlene Jeffers (Mobile Video Services) demonstrated an application designed to serve assessors' offices. A disk containing images of all properties in Wyandotte County, Kansas, was tied to a PC-based GIS (ESRI's ARCINFO). The user

Beach. Supercard is a recent program that complements Apple's hypercard program by adding some impressive features. Supercard also "drives" the videodisk player which stores most of the images relating to the river. The player (a Panasonic OMDR) can hold approximately 24,000 frames of video, each of which can be rapidly accessed and displayed. The system can operate with either two regular-sized monitors (one in color) or one large color monitor.

Future Government Applications

Hypermedia is viewed by many of the large computer companies as one of the next major directions in computing. IBM, Intel, Microsoft, Apple, Sony, and Philips are just a few of the industry leaders investing research.
could click on the computer-generated map and immediately retrieve a picture of the selected property, as well as pertinent data stored in the computer. Kay Cleveland of the Alabama Power Company described the use of laser disks to store information about communities and development sites throughout the state. At the Alabama Resource Center, a visitor can quickly access USGS maps, at four different scales, as stored on the disk, as well as still images and short motion segments highlighting investment opportunities.

More so than most organizations, government is in the business of providing information. Thus, it is easy to think of applications where clear direction or explanation from an easily accessed kiosk would be very helpful. Some private initiatives have sprung up, most notably in airports. Several cities have developed point-of-information disks—Milwaukee and St. Louis, for example. More recently, Public Technology Inc., and IBM developed several prototypes as part of their “City Hall in the Mall” demonstration project.

Education

A growing array of disks is being introduced into schools for the sciences, social sciences, humanities, math, and more. But interactive multimedia may be even more appropriate in alternative educational settings. Systems now exist that help adults learn how to read and write, teach sign language to the deaf, and supplement a growing number of specialized courses. There is a vast potential market for hypermedia systems oriented to the handicapped, the elderly, and other dependent population groups. Cities and counties that run prisons, libraries, hospitals, nursing homes, and shelters increasingly can be expected to offer multimedia systems in the years ahead.

Training

The United States Military has discovered the benefits of interactive video. In recent years, volume purchases of equipment have been made, and interactive programs have been commissioned for hundreds of training challenges. Cities and counties have extensive training requirements that could benefit as well. Interactive multimedia systems are particularly useful in simulating situations that require judgement: When should a policeman shoot, a building inspector condemn a structure for occupancy, or a sanitation inspector close a restaurant? Effective multimedia systems can portray numerous realistic situations with all their complexity and ambiguity, which allow the trainee to make a judgement and then help him or her to understand the implications of that decision.

Decision Support

The St. Louis Riverfront disk is an early example of hypermedia use that will help government officials actually make decisions. The best of these systems will provide background information, then go further to assist the user in seeing the im-
mifications of a given decision. A melding of artificial intelligence and multimedia features can be expected during the ’90s that will help policymakers define a problem and its alternative promising solutions. Such systems will ensure that decision criteria are properly weighed and evaluated and that possible outcomes are understood.

Mandli Communications’ Roadview III system is a good illustration of a promising decision support system. As presented at the 1989 URISA conference, this system ties a microcomputer GIS package (Mapgrafx) to a videodisk-based inventory of highway segments in a state. An analyst is able to select the road segment of interest and then, using the GIS, “drive” the stretch, visually examining the pavement. For any location, the analyst can call up additional data about the road conditions, repair record, and related information (see URISA Journal Vol. 2, No. 1, p. 59). It is easy to envision a family of such systems that assist with planning and analysis for disasters, renewal, capital improvement programming, and much more.

The Next Generation

Unlike the large-scale batch models of the ’60s and ’70s, the next generation of decision-support systems is likely to be more modest in scope, but much more interactive and visual.

Over the next three-to-five years, there will be exponential increases in processing speeds, memory storage, and compression techniques for handling visual images. Already, people such as Ph.D. candidate Mike Shiffer at the University of Illinois are defining new computer-based support systems for use by government officials. Interactive multimedia promises to be an important component of such systems.

For more information about these systems, contact the following people.

C.P. Kindleberger, Director of Research, St. Louis Community Development Agency, 411 N. 10th Street, St. Louis, Missouri 63101 (314/622-3400)

Dave van Bakergem, Director, Urban Research and Design Center, School of Architecture, Washington University, Campus Box 1079, St. Louis, Missouri 63130 (314/889-6253)

Ed Crane, GIS Manager, M.J. Harden Associates, Inc., 720 Troost, Kansas City, Missouri 64106 (816/842-0141)

Marlene Jeffers, President, Mobile Video Services, Inc., 700 E. 8th Street, Kansas City, Missouri 64106 (816/421-0904)

Kay Cleveland, Alabama Power Company, 600 N. 18th Street, Birmingham, Alabama 35291 (205/250-3673)

Greg Coenan, Communications Manager, Department of City Development, 809 North Broadway, Milwaukee, Wisconsin 53203 (414/233-5790)

Ray Mandli, Mandli Communications, 2211-D Parkview Road, Middleton, Wisconsin 53562 (608/836-3344)

Michael Shiffer, Department of Urban and Regional Planning, University of Illinois at Urbana-Champaign, 1003 West Nevada Street, Urbana, Illinois 61801 (217/333-3890)

Charles P. Kindleberger is a past president of URISA with a long-time interest in urban information systems. He has a bachelor’s degree in political science (University of Pennsylvania, 1962) and a master’s in urban and regional planning (University of Pittsburgh, 1965).
"The entire system is down. The computer, people blame the modem, people who blame the phone people who blame it on our moon being in the fifth house with Venus ascending."
The ways of organizing information are finite. It can only be organized by (1) category, (2) time, (3) location, (4) alphabet, or (5) continuum. These modes are applicable to almost any endeavor—from your personal file cabinets to multinational corporations. They are the framework upon which annual reports, books, conversations, exhibitions, directories, conventions, and even warehouses are arranged.

While information may be infinite, the ways of structuring it are not. And once you have a place in which the information can be plugged, it becomes that much more useful. Your choice will be determined by the story you want to tell. Each way will permit a different understanding of the information. Within each are many variations, but recognizing that the main choices are finite and limited makes the process less intimidating.

If you were preparing a report on the automobile industry, you could organize cars by model (category), year (time), place of manufacture (location), or Consumer Reports rating (continuum). Within each, you might list them alphabetically. Your choice would depend on

One of the most striking examples of organization by time is the book 10:56:20 PM EDT, which is about the moments surrounding the landing on the moon. It describes a way of seeing by looking at the time leading up to this event. That focus is the framework that supports, sustains, and propels the book.

The book, put together by Frank Stanton, president emeritus of CBS, Inc., and Lou Dorfman, senior vice president of CBS, Inc., leads up to a singular event, a particular second in our lives when a foot touches the surface of the moon. It slows the moment down—excruciatingly—so you can appreciate the complexity of the accomplishment.

Category

Category pertains to the organization of goods. Retail stores are usually organized in this way by different types of merchandise, e.g., kitchenware in one department, clothing in another. Category can mean different models, different types, or even different questions to be answered, such as in a brochure that is divided into questions about a company. This mode lends itself well to organizing items of similar importance. Category is well reinforced by color as opposed to numbers,
which have inherent value.

**Time**

Time works best as an organizing principle for events that happen over fixed durations, such as conventions. Time has also been used creatively to organize a place, such as in the *Day in the Life* book series. It works with exhibitions, museums, and histories, be they of countries or companies. The designer Charles Eames created an exhibit on Thomas Jefferson and Benjamin Franklin that was done as a time line, where the viewers could see who was doing what when. Time is an easily understandable framework from which changes can be observed and comparisons made.

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**We are, I know not how, double in ourselves, so that what we believe, we disbelieve, and cannot rid ourselves of what we condemn.**

*Montaigne*

---

**Location**

Location is the natural form to choose when you are trying to examine and compare information that comes from diverse sources or locales. If you were examining an industry, for example, you might want to know how it is distributed around the world. Doctors use the different locations in the body as groupings to study medicine. (In China, doctors use mannequins in their offices so that patients can point to the particular location of their pain or problem.)

---

<table>
<thead>
<tr>
<th>Directory Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Yellow Pages Directories</strong></td>
<td>These directories are organized by category and arranged alphabetically, with alphabetical listings within categories. E.g., <em>Attorneys</em> are listed alphabetically together under the heading “Attorneys” in the A’s.</td>
</tr>
<tr>
<td><strong>Pacific Bell SMART Yellow Pages</strong></td>
<td>Special nonalphabetical index of Yellow Pages directory category headings, organized by broad subject category like “Automobile” with alphabetical listings underneath.</td>
</tr>
<tr>
<td><strong>Dictionary</strong></td>
<td>Words, in alphabetical order. Definitions are organized by category of meaning; etymologies are organized by time.</td>
</tr>
<tr>
<td><strong>Goode’s World Atlas</strong></td>
<td>The overall organization is by category, according to type of map (themetic, city, or regional). The information within this sections is then organized by location.</td>
</tr>
<tr>
<td><strong>World Almanac</strong></td>
<td>Organized by subjects (categories) and within these by all five ways as listed in the key, to varying levels of organization (some as many as three levels deep).</td>
</tr>
<tr>
<td><strong>Books in Print Series</strong></td>
<td>Each multi-volume set is organized alphabetically within a category (e.g., there is a three-book set on authors, in which authors are listed alphabetically).</td>
</tr>
<tr>
<td><strong>Sears Catalog</strong></td>
<td>This catalog is organized by category, and within these, by continuum of either price or sophistication. The index is then organized alphabetically.</td>
</tr>
<tr>
<td><strong>SPY Magazine</strong></td>
<td>Most magazines are organized by category; features are secondarily organized by time, like a story. The features in <em>SPY</em> are in many cases organized in innovative ways—by location, continuum, time, or category.</td>
</tr>
<tr>
<td><strong>USA TODAY</strong></td>
<td>Like most newspapers and magazines, <em>USA TODAY</em> is grouped into categories and then organized along a continuum of importance as seen by the editors of the paper. Television news is grouped the same way, although the categories are very often the shows themselves (local news, evening news, 11:00 news, etc.).</td>
</tr>
</tbody>
</table>

(continued)
Alphabet

This method lends itself to organizing extraordinarily large bodies of information, such as

... Don’t be too certain of learning the past from the lips of the present. Beware of the most honest broker. Remember that what you are told is really threefold: shaped by the teller, reshaped by the listener, concealed from both by the dead man of the tale.

Vladimir Nabokov, 
The Real Life of Sebastian Knight

words in a dictionary or names in a telephone directory. As most of us have already memorized the twenty-six letters of the alphabet, the organization of information by alphabet works when the audience or readership encompasses a broad spectrum of society that might not understand classification by another form such as category or location.

Continuum

This mode organizes items by magnitude from small to large, least expensive to most expensive, by order of importance, etc. It is the mode to use when you want to assign value or weight to the information, when you want to use it to study something like an industry or company. Which department had the highest rate of absenteeism; which had the least? What is the smallest company engaged in a certain business? What is the largest? Unlike category, magnitude can be illustrated with numbers or units.

We already employ these modes almost subconsciously in many ways. Most of us organize our checkbooks first by time, then by category when we figure our taxes. We organize our recorc collections, libraries, and even our laundry according to certain principles whether or not we are aware of them. But it is only the conscious awareness of these methods that will reduce the frustration of searching

| EPCOT Center | The organization of a place can be in any of the five ways—not just by location as is EPCOT Center, but by national cultures, historical eras, etc. |
| Powers of Ten | Information and photographic plates range in scope from gigantic to microscopic. |
| Information Anxiety | Information arranged by topics (chapters). |
| State of the World Atlas | Pages arranged by topic with maps (location) and charts (continuum) related to specific topics. |
| A Conversation | A conversation has no determined flow or pattern and moves sequentially through different topics. |
| Romeo and Juliet | Like most stories, novels, and jokes, this book is organized by time. Most television shows and commercials are organized in the same way. |
| Disneyland | Unlike EPCOT Center, Disneyland is organized by category (Adventureland, Frontierland, etc.). These are categories and not locations because they are not based on real places, but on combinations of real places. |
| Roget’s Thesaurus | Words are organized alphabetically, but the synonyms under each word are organized along a continuum based on proximity to the meaning of the base word. |
| TV Guide | Usually, television schedules are organized by time, and television movies are organized alphabetically. There are also indexes for children’s programming and for sports events. |
| Sears Tablesaw Owner’s Manual | The manual is broken into categories. Some of these are organized by time (the assembly and operation sections), some by location (the parts map), and others by still more categories. |
| Richard Scarry’s Children’s Books | Instead of being arranged by time, as a story is, many of these books are arranged by category, continuum, location, and alphabet. |
| A Hospital Emergency Room | Emergency rooms are usually organized along a continuum of importance or likelihood of need. Items most often needed are closer to doctor and patient. |

(continued)
through information—especially new information. Uncovering the organizing principles is like having the ultimate hatrack. It is as essential when working with already existing bodies of information as it is in developing your own information programs. The time spent in comprehending someone else’s method of organization will reduce the search time spent looking for individual components. When you arrange location, the structure you create will save you the frustration of juggling unconnected parts. Many people get into trouble when they mix the different methods of organization, trying to describe something simultaneously in terms of size, geography, and category without a clear understanding that these are all valid but separate means of structuring information. Understanding the structure and organization of information permits you to extract value and significance from it.

The ABCs are drummed into schoolchildren so early and in such a rigorous way that this system of organization sometimes seems as if it’s God-given. But it isn’t: only a cultural consensus puts L before M instead of the other way around.

Vantage Points

Once you have a sense of organization, however casual, you can relax with that knowledge and begin to examine the information from different vantage points, which will enable you to understand the relationship between bodies of information. Ask yourself: How can I look at this information? Can I move back from it? Can it be made to look smaller? Can I see it in context? Can I get closer to it so it is not recognizable based on my previous image of the subject? Can I look at the detail? Whatever problems you have in life—personal relationships, putting together a business deal, designing a house—can be illuminated by asking these questions. How can I pull myself out of the situation? How do I see it
by changing scale? How can I look at the problems from different vantage points? How do I divide it into smaller pieces?

Mozart was once criticized by his patron, the Emperor of Austria, who told him that his music contained too many notes. The Emperor suggested that a few of them could be cut. Mozart responded by asking which few did he have in mind.

How can I arrange and rearrange these pieces to shed new light on the problem?

In Holland, telephone directories were recently reorganized to reflect different geographical areas. The country, which has a population of about 10 million people, used to have 29 directories; the number was then raised to 40. Now, the number is being reduced to 10. Essentially, this rewrites the "chapters of the country," for that is what a phone book is. The restructuring will change the way advertising dollars are spent throughout the country. Where it was once feasible for a shoe repair store to advertise in a directory that covered only one city, it becomes impractical in a directory that covers several cities.

In Portugal, where the postal and phone systems are run as one entity, there is both a conventional yellow pages directory organized by subject headings and one organized by postal codes, where you can look up a particular street and find out all the businesses on it. This gives you a new way to look at
cities and provides invaluable information to anyone contemplating the new location of a company or residence.

Each vantage point, each mode of organization will create a new structure. And each new structure will enable you to see a different manner of meaning, acting as a new method of classification from which the whole can be grasped and understood.

THE GREAT DIVIDE

As far as many statistical series related to activities of mankind are concerned, the date that divides human history into two equal parts is well within living memory. The world of today . . . is as different from the world in which I was born as that world was from Julius Caesar's. I was born in the middle of human history, to date, roughly. Almost as much has happened since I was born as happened before.

Economist Kenneth Boulding, quoted by Alvin Toffler in Future Shock

Classifying Lassie: The Dog Story

I could contact Avanti, an Italian company that makes stuffed animals, and ask them to make me a set of 260 life-sized dogs representing a male and female of each of the 130 breeds recognized by the American Kennel Club. Now I want to make the dogs understandable to people. I would put this extraordin-

<table>
<thead>
<tr>
<th>Afghan Hound</th>
<th>Chihuahua</th>
<th>Komondor</th>
<th>Labrador</th>
<th>Pomeranian</th>
<th>Poodle</th>
<th>St. Bernard</th>
<th>Standard Wirehaired Schnauzer</th>
<th>Fox Terrier</th>
</tr>
</thead>
</table>

or by category (country of origin, for example)

<table>
<thead>
<tr>
<th>Egypt</th>
<th>England</th>
<th>Germany</th>
<th>Hungary</th>
<th>Switzerland</th>
<th>Newfoundland</th>
</tr>
</thead>
</table>

or by time (for instance, according to the year in which the breed was officially recognized by the American Kennel Club).

| 1885 | 1887 | 1888 | 1898 | 1904 | 1904 | 1917 | 1926 | 1937 |

Then I would arrange them from the smallest to the largest, from the shortest to the tallest, from the lightest to the heaviest, from the shortest-haired to the longest-haired, by their level of viciousness, popularity in the United States, population, price, and the number of championships they have won.

I could organize these dogs alphabetically . . .
Then again, I might arrange them by weight in pounds,

4 11 18 19 40 60 70 90 175

by height in inches (other kinds of continua),

5" 10" 15.5" 17" 19" 23.5" 25.5" 27" 27.5"

or by breeds as categorized by the American Kennel Club.

Hounds  Toy Dogs  Nonsporting Dogs  Sporting Dogs  Terriers  Working Dogs

Real learning about the dogs comes from comparing organizations. For example, you can see that the Afghan hound is taller than both the Labrador retriever and the komondor, but is outweighed by both. Most likely they are stockier, which makes sense when you see that they are both in the working dogs category while the Afghan is a hound.

Every time the dogs are arranged in a different way, you can start seeing new information about the relationships. You might see that the most popular dogs are the shorter-haired ones, or that the most expensive dogs are the small dogs, or that in certain breeds the females are bigger than the males, etc.

You can do this with many things; it makes your mind work differently because it shows the importance of relaxing and thinking about the arrangement of information before you make it complex. It’s a process of simplification, not complication. And you realize that by simplifying, by taking one point of view, one slice, you can make something terribly clear. Whereas if you tried to say this dog is the most popular in Wisconsin, and is of medium height, and said all these things at once, you would never get the mental map in your head, nor would you retain the memory of the information. Each way that you organize the information creates new information and new understanding.
A Terms and Definitions Sampler
Kenneth J. Dueker and Daniel Kjerne

Any field undergoing rapid development necessarily endures some confusion in terminology. Recognizing the need for a comprehensive and current compendium of industry terms and definitions, the American Congress on Surveying and Mapping (ACSM) and the American Society for Photogrammetry and Remote Sensing (ASPRS) provided grant funds to the Center for Urban Studies at Portland State University for a "definitive" project. Kenneth Dueker, of Portland State University, and Daniel Kjerne, of the University of Washington, set to work collecting, synthesizing, and formulating the terms and definitions related to multipurpose cadastre systems.

To accomplish this goal, they adapted the Delphi process in which terms and associated candidate definitions were assembled and presented to a pool of recognized experts in the field for comments and consensus. Dueker and Kjerne pursued the comments through three iterations, condensed the comments, edited the definitions, and sent them to the experts again, until unity was reached. The resulting list of "core" terms and definitions, published by ACSM and ASPRS in a booklet called Multipurpose Cadastre: Terms and Definitions, represents their successful strides toward a common vocabulary.

Below is a sampling of the terms and definitions for which a high or moderate degree of agreement was reached. Following the term and definition, the fuller "explanation" expands and supplements the definition with amplifying materials the respondents felt was important but not essential.

Kenneth Dueker is the director of the Center for Urban Studies at Portland State University and a coordinating editor of the URISA Journal.

Daniel Kjerne is a Ph.D. candidate in geography at the University of Washington. He received his M.S. in geography at Portland State University.

Automated Mapping and Facilities Management (AM/FM)

The use of a computer-aided mapping or geographic information system for public works and utility information management and similar applications.

Explanation
In general, basic functionalities allow the assignment of attribute data to specific elements in a layer, assigning positions to facilities, and the production of planimetric and thematic maps of the base and infrastructure layers. Some support the construction of a linear network model for the connectivity in such a system, and analytical functions unique to the class of infrastructure being modeled, such as materials lists, work order generation, and plan and profile.

Notes
Wide agreement.
Geographic Information System

A system of hardware, software, data, people, organizations, and institutional arrangements for collecting, storing, analyzing, and disseminating information about areas of the earth.

Explanation
Requisite functionality for a GIS consists of: (1) the ability to create, edit, and delete geographically structured data; (2) the ability to link locational and attribute data; (3) the ability to perform spatial analysis functions, including analytical map overlay of multiple data themes and network analysis; (4) the ability to display geographic information. Geographic data editing and network analysis are both facilitated by use of a topological data structure that describes objects as points, lines, and areas and records the relationships of incidence and connectivity among them.

Notes
Only moderate number of explicit votes to concur with the definition as it appeared in the final round, but it seems likely that the changes made in response to suggestions bring it into line.

Land Information System

A geographic information system having, as its main focus, data concerning land records.

Explanation
Land records are broadly defined to include resource, land use, environmental impact, and fiscal data.

Notes
Only slight consensus on the candidate definition. From the comments, it appeared that respondents understood “land records” as implying a narrow focus—cadastral and property records—and they wanted LISs to cover more than that.

Multipurpose Cadastre

A parcel-based land information system.

Explanation
The basic components of a multipurpose cadastre are a geodetic reference frame, a base layer that uses the geodetic reference frame for control, and a cadastral overlay that is controlled by references to both the geodetic reference frame and features on the base layer. Multipurpose cadastre systems also integrate a large number of other parcel records keyed to a unique parcel identifier. These ancillary records may include information used for legal reference (legal cadastre), data related to land valuation and taxation (fiscal cadastre), and information used for resource and facility management (resource cadastre).

Notes
Only moderate concurrence with this definition/explanation. The majority opinion on spelling is for -re rather than -er. One suggestion that the term be labeled “archaic.”
Base Layer

A set of information that provides a spatial framework and background orientation for another set of information of primary focus. Synonyms: land base, digital base map.

Explanation

In the National Research Council's specification for a multipurpose cadastre, a base layer is the standard set of information that will be used to control all other map sources and includes all specific spatial controlling features such as the geodetic control network as part of its structure. It is analogous to the "base map" — the graphic representation at a specified scale of selected fundamental map information, used as a framework upon which additional data of a specialized nature may be compiled on conventional cartography. Depending on context, the same set of information could at one time be considered base layer information and at another time be considered the primary information.

Notes

High concurrence for minor rearrangement of explanation.

Geocode

A data value, assigned to a spatial object, that provides information on the geographic location of the object and is used as a key to access data relating to the object.

Explanation

A coordinate, a street address, and a census tract number are all considered geocodes. Place names, e.g., city and county names, are nominal level geocodes that require users to know relationships among named places, whereas coordinates are ratio level geocodes that enable spatial relationships among geocoded places to be calculated. Some coding systems combine characteristics of nominal and ratio level geocodes. For instance, some parcel identification coding schemes based on a hierarchical organization allow one to find a parcel using coordinates within a (named) partitioning of the area.

Notes

Broad consensus on this one, except for one comment disputing the inclusion of coordinates as a geocode.
FEATURE MAP

Statement of Editorial Intent

A good picture is worth several thousand words, and so is a good map. Pages of data can be summarized in a single map, and spatial patterns become apparent that are impossible to discern among pages of numbers or words. We use the word “map” in a very broad context and are willing to consider remotely sensed images and other graphics.

Computer mapping and geographic information systems play a key role in URISA’s mission to help local, regional and state/provincial governments make the best use of information system technologies. And now that computer-generated maps have become an important part of URISA’s domain, the URISA Journal intends to showcase the efforts of mapmakers by featuring an exceptional map product in each issue. Our intent is to share a wide variety of maps, hoping to inspire others to learn and copy good ideas and techniques.

We are looking for maps that are easy to read and that allow the reader to readily see what the mapmaker intended. Perhaps new symbols were designed or special colors chosen to meet a particular purpose.

New ways of presenting data or of understanding phenomena through mapping techniques are also desirable. And, of course, we will also consider publishing a map that is exceptionally pleasing or beautiful.

William J. Craig

GUIDELINES FOR FEATURE MAP SUBMISSION

1. The focus of the map section is on the image itself. We will consider both color and black-and-white submissions. You may submit a complete map, an enlarged portion of a map, or both. Depending on the size and nature of the map, we may print two different scales: the full map at a reduced scale and a portion at full scale. The following criteria will be taken into account: visual quality of the map; amount and quality of information transmitted; and reproducibility of the map within the journal context.

2. We prefer original maps provided they are clean and that you indicate the portion you wish to be published. As an alternative, we will accept glossy 8 × 10 color or black-and-white prints. Slides are acceptable but must be accompanied by a print. All submissions should be of high quality. This is especially important for computer-generated images, which can be difficult to reproduce.

3. Two to six double-spaced pages of text should discuss the map and its construction.

4. Include a separate page with the title, and author’s name and address. Also include, on this page, a two- or three-sentence biographical sketch summarizing the author's professional positions, current affiliation, and research interests.

5. Any acknowledgement must be included at the end of the text under the heading: Acknowledgements. If your submission is a copyrighted image, please contact the map section editor to make special arrangements.

6. Submit map materials and text to the section editor:

William J. Craig
Center for Urban and Regional Affairs
330 Humphrey Center
University of Minnesota
Minneapolis, MN 55455
Anatomy of a Database
Beth Flynn and Lester Garvin

Editor's Note: The original map produced by Flynn and Garvin measured 3 by 4 feet. We have reproduced the full map in a greatly reduced form, hoping that the basic ideas and visual impact would be retained.

We have selected one portion of the map, Section 2, to be reproduced at much closer to original scale. The original measured roughly 9 by 9 inches. The authors' text conveys several interesting aspects about this particular section.

Anatomy of a Database is an outgrowth of a project in Sutton, Massachusetts where multiple data layers were developed to analyze conflicting zoning, natural resource and land uses within the community and its neighbors in the region. This map has proven useful in illustrating the project.

The graphic is a data "sampler." To make it, the town of Sutton was divided into nine sections, each depicting one or more of the data layers that are part of Sutton's database. The chart shown at right is a key part of any GIS database. It documents the source maps used to build Sutton's database and indicates which layers of digital information were generated from each source. Source map scales ranged from 1" = 200' to 1" = 4,000'. An assessor's map index,
the location of Sutton within the Massachusetts universe, north arrow and, of course, scale complete the graphic content.

**Reading the Map**

The nine map sections or “tiles” are numbered left to right, top to bottom. The parcel map and water bodies comprise the base map which is present in all nine sections (see Section 5).

**Section 1, Septic Suitability,** represents a soils map derivative where soils attributes relating to on-site sewerage disposal system constraints are mapped.

**Section 2, Land Use/Land Cover,** relates land use/land cover (as interpreted from 1:25,000 scale aerial photographs) to the parcel database. Residential areas have not been color coded. Note the correlation between the white areas and the small residential parcels. Also note the encroachment of industrial sand and gravel operations (purple shading) on the 400’ radius circle (right center) representing the town’s public well area. The sand and gravel operations in proximity to the public well area, however, are legal, being zoned industrial. This same area is also shown as having a thick layer of stratified drift and designated by the Commonwealth of Massachusetts as a high-yield aquifer. This is an area of severely conflicting land uses.

**Section 3, Infrastructure,** shows the location of water and sewer mains. Data were developed by providing the local water and sewer commissions with the digitized parcel base map and having them draft the location of the mains on that base.

**Section 4, Hydrography,** integrates wetland data from the Central Massachusetts Regional Planning Commission, with open water and streams from local assessor map sources and drainage basins from MassGIS (Massachusetts Geographic Information System).

**Section 5, Center,** shows Sutton’s base map produced by digitizing parcels (black lines), streams and open water (blue) from an atlas of 55 1”=200’ Class A maps. Map sheets were edge-matched to produce a seamless parcel base. Parcel numbers, zoning class and assessor’s land use codes were attached to each parcel as attributes. This map also shows powerline and gas pipeline easements in red.

**Section 6, Land Use by Parcel,** was produced by plotting the land use as defined by assessor’s land-use codes. A great deal of confusion exists concerning the term “land use.” Some professionals refer to natural boundaries as interpreted from aerial photographs or field mapping. Others think in terms of land use within parcel boundaries. Comparison of land use by parcel and land use/land cover shown in Section 2 illustrates the difference between the two concepts.

**Section 7, Cultural, Natural and Historic Resources,** was developed through cooperation with local organizations. The Sutton parcel base maps were provided to the Sutton Historic and Recreation Commissions for locations of resources and descriptions of their significance. The area shaded in light green is on the National Register of Historic Places as the Water’s Farm, site of the development of Baldwin Apples.

**Section 8, Zoning,** shows four types of zoning districts. Being a rural community with a current population of approximately 6,500 and a land area of 34 square miles, much of the town
is zoned rural residential. In this zoning district, private wells and
individual septic disposal systems are included within each residen-
tial lot zoned to a minimum size of two acres.

Section 9, Soils, is an example of
multiple map derivatives from
soils information. Gravel pits are
accentuated with mining tools
symbology. Two levels of farmland are shown: prime farmland
as defined by the United States
Department of Agriculture, and
farmland of less rigorous defini-
tion referenced as farmland of
state or local significance. Soil
slope attributes have been ex-
tracted from soils units to show
areas in excess of 15 percent.
While the slope information is
generalized, it provides a good
indication of land development
constraints.

Value and Applications

Anatomy of a Database
has proven to be very valuable
for illustrating the concepts of
spatial databases and data layers
without having to carry and sort
through multiple overlays and
base maps. It is useful for show-
ing the range of data available
and for hinting at data applica-
tion for highlighting problems.
With soil survey and assessor’s
records, the Anatomy is espe-
cially useful for explaining the basic
GIS concept of matching at-
tribute data to spatial units.

It sometimes takes a few
minutes for the audience to
realize that the graphic is a map
data sampler designed to illus-
trate what a variety of informa-
tion would look like if completed
for each sample. This gap can be
reduced by showing one of the
overlays as complete for the
town over the parcel base map.

Similar graphics could be
produced from GIS or CAD sys-
tems to show infrastructures,
utilities or a sample of natural
resources of any type or for any
area. This graphic is equally use-
ful in the classroom or as a pro-
motional piece for presenting
concepts to potential clients. It is
aesthetically pleasing and can be
displayed for these characteristics
alone. At IEP we display the
Map of the Month in our recep-
tion area. It’s a way of encourag-
ing high-quality map composi-
tions from GIS analyses while at
the same time showing company
capabilities to visitors.

Anatomy of a Database
was initially prepared as an entry
for the Northeast ARC/INFO
Users Group fall meeting poster
session (1989).

Beth Flynn is the manager of GIS
operations for IEP’s national
headquarters in Northborough,
Massachusetts. Prior to joining
IEP, she played a key role in
building the MassGIS database
while employed in the Boston
office of the United States Geo-
logical Survey. Her professional
interests lean toward develop-
ment of GIS tools for cost-
effective applications.

Lester Garvin is the GIS
division manager for the IEP
Corporation. His background in
remote sensing, overhead recon-
naissance, natural resources man-
agement and computer graphic
systems provides a sound basis
for supporting in-house scientific
investigations and comprehensive
planning projects using GIS
technology.
URISA Crossword Puzzle
Margaret Norman

ACROSS
1. Silicone circuitry
2. Global Positioning ______
3. An efficient way to store data
5. Sits on the San Andreas Fault
6. Just ______ Stories
8. Dot pictures
9. There will be 18 in the GPS
10. Group of bytes treated as one unit
11. W. coast metropolis
12. Two at a time
13. There's one in Montana, New York, Ohio and Peru
14. G. Bush's vacation spot
15. ______-function rounds decimals down
16. Home of TVA
17. Geographic Info. System
18. Changes mid-Pacific
19. Has length, direction, and at least two points
20. Describes locations of a point

*The crossword puzzle solution is on p. 89.
42. Western-most of the Aleutian Islands
47. Measure twice, cut ______
48. It takes more than one to run a computer
49. Artificial Intell.
50. The main line
51. Red, Med., and Dead are three
52. Usually represents continuous common boundary
53. Overlay of data
57. Summertime in NY
59. Str. Index Guide
61. List of options
62. Assoc. degree in Engr.
63. To, or not to
64. International auto insignia from Denmark
65. Roller controller-hand command
66. Could hold you in the tropics
67. You might need these to survey Marie Byrd Land
68. Am. Planning Assoc.
69. The end of many
70. Input/Output
71. What you might call a buy from Big D
72. Group working together
74. Plain Old Tele. System
77. Spoken around 68° East Longitude, 25° North Latitude
78. Location
79. The smallest picture element
81. This _______ that
82. Long for Rd.
83. Leave your message after the _______
84. Verbal
87. Worldwide engineering assoc.
88. Ears often do during descent
91. Himalayan kingdom
93. Sometimes it's best to do it your _______
94. Disintegrated rocks and humus
95. Horizontal direction measured clockwise from North
96. Sample of what's possible
97. Description of land areas

DOWN
1. In 1860's they tried to create new borders in N. Amer.
2. Course through a data structure
3. Tangent, cosine, ______
4. Help!
5. Magnetic storage device
6. In abundance at 0 Latitude, 0 Longitude
7. A _______ order
8. Large Scale Integ.
9. City parcel
10. Survey that defines boundaries
11. CON ______
15. Computer in 2001
16. Small town about 35° North
   Latitude, 121° West Longitude
17. Read Only Memory
19. Topologically Integrated Geographic Encoding Ref.
20. Angular distance north or south of the equator
21. Line linking two nodes
22. Group of bits
23. Defined shape which stores data
26. User Interface
31. Indigenous around 175° East
   Latitude, 40° South Longitude
32. Things known about real world entities
33. Nongraphic data
34. Greek maiden loved by Zeus and turned into a heifer by Hera
36. Point common to two or more lines
37. Imaginary lines above or below a surface
38. _______ line
39. Identified subset of geographic database
40. Numerical Aperture
41. Collection of records
42. A two-dimensional defined space
43. Can quickly alter geographic features
44. Home of Stephen Hawking
45. Info. System
46. Blocks partial transfer of film image
55. Major river spanning Alaska
56. Pattern of horizontal parallel scan lines
58. Aspects of earth's surface
59. _______ terminal
60. _______ line
61. Representation of a region
63. Petroleum Co. from GB
64. Def. Mapping Agency
68. River in Central Switzerland
73. An example to be followed
74. Parcel Id. Number
75. Indonesian workhorses
76. Represented by variously spaced machineries
77. Foremost information system association
79. Power On Syst. Test
80. Ring around the moon
81. _______ a new window
86. Req. for Proposal
88. Where the Liberty Bell dwelling
89. Accessible via tornado
90. 3.1416
92. Editor in brief

Margaret Norman is a research analyst for PlanGraphics, Inc. in Frankfort, KY. She is involved in proposal writing, industry and market research, writing press releases, and special marketing assignments.
REVIEWS

Statement of Editorial Intent

The reviews section of the URISA Journal provides critical reviews and information concerning publications, information sources, and software in the field of urban and regional information systems. Professionals in this field must draw from a variety of sources and materials to support their activities. Accordingly, this section will include reviews of a variety of information sources that, in general, fall into one of four broad categories:

1. **Book reviews** will focus on books relating to the development, implementation, application, evaluation and management of information systems in urban and regional environments. Books written for use in academic settings, as well as those aimed at the practitioner, will be included.

2. **Publication reviews** will examine a variety of publications that offer significant contributions to URISA's area of interest. These will include conference and symposium proceedings, reports, resource papers, monographs, technical publications, development guidelines and manuals related to urban and regional information systems issues.

3. **Video reviews** will provide another review category, because videotapes are becoming a popular tool for education and information dissemination, particularly in the area of geographic information systems. The URISA Journal will include reviews of new videos that could be useful information sources or tools for journal readers.

4. **Software reviews** will also be a feature of the reviews section. They are intended to help readers become aware of software that could aid them in their work, and to help them choose the right software by reviewing it from a URISA professional's viewpoint. The software reviews are categorized as follows:

   - **In-Depth**: Detailed reviews of substantial programs. An In-Depth Review covers areas including ease of use, performance, and support. A program summary and overall rating complete the review.
   - **Head-to-Head**: Program comparisons that take a class of programs such as thematic mapping software, introduce each package, compare their strengths and weaknesses, and discuss their use.
   - **From the Inside**: Explanations of non-commercial programs by their creators, to inform readers about program capabilities and encourage use of the programs.

As with all reviews, software reviews express the opinions of the authors. The publishers of commercial software will be given the opportunity to check review drafts for factual errors, but cannot change opinions expressed in the reviews. URISA Journal does not encourage complimentary submissions of software for review. We prefer that software publishers identify expert users of their software and then encourage them to write a review. Potential reviewers are encouraged to evaluate programs they use frequently, decide whether those programs would be of interest to journal readers, and find out if the programs have been adequately reviewed elsewhere. Many programs useful for our professions are not reviewed, or are reviewed by journalists, rather than by members of our professions.

In addition to submissions of book, publication, video and software reviews, we welcome suggestions and insights pertaining to the identification, critical review, and recommendations of all information sources in the field of urban and regional information systems. (See p. 87 for guidelines for submission of review materials.)

Rebecca Somers
Peter Van Demark
BOOK REVIEWS

How to Model It: Problem Solving for the Computer Age


Reviewed by William J. Craig

How to Model It arrived in the mail from the publisher a few months ago. Generally, I do NOT read work-related material at home in the evening, but somehow this little paperback became part of the fun of my day.

This book was written for the classroom, but it is good reading for anyone with an inquisitive mind. The authors start each chapter with a problem that needs to be solved. In each case they present the problem, then usually ask the reader to take 10 minutes to an hour to figure out how to solve the problem. This is a technique they have found useful for teaching modeling in the classroom. They often have students work in teams, but it is just as much fun to work on your own at home—and just as instructive. Their style is personal and probing. I had the feeling they wanted feedback from me, were interested in my learning, and were checking if I cheated and read ahead.

Chapter 2 begins: ‘Look around the room you are sitting in. Take just 60 seconds to answer the following question: ‘How many ping-pong balls could you fit into the room?’ . . . Time’s up! What is your answer?’ This is quickly followed by: ‘How did you get it? . . . Did you build a model? If so, can you describe your model?’ After asking the reader a number of questions like, “If you made a volumetric calculation, what was your model of a ping-pong ball?”, the authors ask the reader to rework the problem with a five-minute limit. Their intention is to get you, the modeler, to work within your time and other limits. They want you to be able to extract the essential details and ignore the rest.

My approach was to treat the room and ping-pong balls as cubes, with a rough guess on the room dimensions and a one-inch cube ball. Then I allowed a 20 percent vertical compaction (a better adjustment was 14 percent; somehow I forgot about horizontal nesting). The authors asked me about ignoring furniture, in my case the neglect was an oversight, not an explicit decision. This is one of their lessons. Be explicit in building your model, it will allow you to build a better solution and allow you to talk about the results. The authors ask you questions as you work and demand an answer. Their goal is to get you to ask the questions of yourself.

Each chapter starts with an interesting question, the type that a reader of Arthur Conan Doyle might appreciate. This may be the reason I enjoyed this book so much. It was like reading a good mystery. I could work out my own version of how the murder was committed, then read on for more clues and a critique of my solution.

Chapter 3 presents a problem with no obvious answer: A methane tank needs to be emptied for cleaning and inspection. How much methane do you need to pump through to dilute the mixture to 1 part per 1007? At the upper bound, you simply overpack the tank with a 100:1 ratio of nitrogen, then release the pressure. Bounds need to be determined at both ends, then narrowed. Schematic drawings and equations help to refine the process. The authors provide guidance and show how students have dealt with this problem in
class, but leave it to you to build a model and implement it. There is no algorithmic, correct answer to this problem. It must be pursued with heuristics, which close in on an answer of acceptable quality. Much of the chapter is spent trying to help you think about how to select fruitful paths in building your heuristic model.

Chapter 4 helps you learn to build models dealing with rates of change, based on the need to cool beer to a drinkable temperature. Chapter 5 introduces probability into modeling as you need to appraise the odds on the outcome of a tennis match.

Chapter 6 deals with critical paths for the chef trying to get a multi-course meal on the table. Chapter 7 covers constrained multi-objective maximization using the student who has some money for tutors and too little time to cram for finals. Chapter 8 requires some computer simulation in deciding how to balance efficiency of trains with comfort and safety on a new rail line.

Chapter 9 requires building a risk-avoidance model. Chapter 10 has the reader build an artificial intelligence model.

Chapter 9 might be my favorite, because it comes close to meeting needs in my real life as a university administrator. This is the “case of the dishonest advertiser.” The culprit has been caught advertising for help at top pay (indeed, it is not my problem in academia), hiring secretaries at low wages during a trial period, and firing them before the trial period was over. The judge has selected 10 new applicants and has told the employer to hire one at top salary and live with the decision for 20 years. The twist is that the applicants are to be interviewed in random order and with a hire/no-hire decision made at the end of each interview. You know the odds of finding a good, average, marginal, and poor secretary in the population. You have been hired to advise the boss on the best strategy. (How well have you done with your own secretary?)

If there is a constant theme in each chapter, it is to keep algorithms as simple as possible. It has been the experience of the authors that “people are always suspicious of the need to simplify until they have experienced it themselves” (p. 150). The authors frequently urge you to simplify the problems to their essence, ask questions about what you don’t know, and find an acceptable solution with your given resources.

For each problem, the authors spend time helping you develop your approach. Models are put forward, critiqued, and revised—all in a style that seems caring and conversational. While significant effort might go into finding the answer, more credit is given for devising a workable means to find the solution. The purpose of the book is to teach modeling, not to solve problems. I preferred working out the means, and often neglected the answer altogether.

At the end of most chapters the authors present related problems that readers could pursue themselves. The authors also provide a section reflecting on the purpose of the chapter and what specific approaches they wanted the reader to learn. Each chapter closes with an annotated bibliography for those who would like to pursue a given topic in more depth. Thus, while the book is only 206 pages long, it covers much territory and opens the avenues to expand on what is covered in this very nice volume.

If there is a shortcoming to the book, it is found in the subtitle, Problem Solving for the Computer Age. The authors harbor a hope, as stated in their preface, that knowledge of modeling will encourage people to start using computer application packages. Only Chapter 8 requires a computer—and then only for solving the problem, not for setting up the model. Other chapters would benefit from access to a computer, such as Chapter 7, but here the question becomes: should the reader use a linear programming package or write computer code? The reader needs guidance in determining how to apply computers in the problem-solving process. Similarly in Chapter 1, the authors give some attention to spreadsheet programs as useful tools, but never return to that tool to help the reader see how to set up one of the necessary solutions on a spreadsheet.

I don’t see this as a major shortcoming, but I was not using a computer to actually solve these problems. My pleasure was in building the models. I wish I knew more about spreadsheets and would have welcomed the opportunity to learn on this group of problems, rather than the accounting tutorial problems.

My work, and the work of many professionals in the field
of urban and regional information systems, requires building and using models of human settlement and natural systems. Many of the models are used in GIS applications and the GIS software acts as the computer base. Some of those models are well documented and well understood, but many are seat-of-the-pants solutions. All too often the GIS software, or my familiarity with it, becomes the limiting factor. It was good to focus on models without the software constraints. This book makes good reading for people like me.

I never had a course in "modeling," but have used it most of my professional life. This book has been a useful review of modeling approaches, and has helped me classify them. The book has helped me think about my good habits (simplicity) and bad (not explicit enough, especially regarding implicit assumptions and not performing sensitivity analyses on my results) in building models and pointed me toward using better approaches in the future.

It is useful to look at the background of the authors. Tony Starfield is an applied mathematician who has worked mining engineering problems and environmental management in African game refuges. Karl Smith has bachelor's and master's degrees in metallurgical engineering and a Ph.D. in education psychology. Andrew Bleloch is a physicist in England who worked with Starfield in Africa and on a previous book on modeling: Building Models for Conservation and Wildlife Management. Clearly the authors have solid technical credentials, yet have been drawn to write a straightforward, entertaining book which can help teach modeling to anyone with an interest in the subject and no more than high school algebra and geometry.

If this book is written for the undergraduate classroom, and it is, I wish I were back in my sophomore year. Things seem much better than when I went through school some years ago. Fortunately, the book is available to those of us who have graduated, but want to continue learning—especially if it is as much fun as presented here.

William J. Craig is director of the Minnesota Center for Survey Research at the University of Minnesota and assistant director of the Center for Urban and Regional Affairs. He holds a Ph.D. in geography from the University of Minnesota. He was president of URISA, 1986-87, and is the URISA Journal's feature map editor.
Bringing an understanding of GIS technology and its uses to those not working in the industry is a very difficult assignment. Understanding the potential applications for such systems and the uniqueness of the computer technology used is beyond the knowledge level of most people, even those with a strong aptitude for normal business computer usage.

Stan Aronoff has attempted to make this task easier for all of us in his recent book entitled Geographic Information Systems: A Management Perspective. Instead of providing a highly technical volume aimed at the information systems or geography professional, Aronoff has directed his efforts towards the ultimate end-user of the system. In doing so he covers many aspects of the GIS implementation issue, from its design to its use. He also sends a strong message to the reader that geographic information systems are a powerful tool for the future to help the human race solve many of the complex problems we face today.

The book is framed with a strong introduction and conclusion that reflect this important message concerning the need for GIS technology in our modern lives. These passages do not dwell on the intellectual definition of a GIS, but instead discuss what the systems can be, and how they can be applied in a manner from which we will all benefit. Through examples of applications in agriculture and land-use planning, forestry and wildlife management, municipalities, and others, Aronoff reiterates this statement, while helping the reader understand the capability and relevance of the technology in our daily lives.

This strong introduction to the GIS environment is accompanied by several examples of GIS outputs in color plates. These illustrations support the author's point that GIS technology can be, and in fact is, in use in very practical ways today. They also illustrate some uses of remotely sensed information in the study of a wide range of modern issues, such as climate forecasting and mineral exploration.

Aronoff begins with a brief chapter concerning GIS definitions, and sets down the components of a GIS. This high-level outline of components includes data input, data management, data manipulation and analysis, and data output. These four components form the foundation around which the following several chapters are based.

Data input is a major focus of the book, and the author demonstrates a deep understanding of remote sensing as a primary source of GIS input. Though the amount of information on remote sensing presented is impressive and easy to follow, it is overly detailed for the managers for whom the book is intended. Details of satellite specifications and similar information are unlikely tools to be used by a manager involved in a GIS implementation.

The focus on data input continues with a chapter devoted to the methods used to place data into a GIS, including scanning, manual digitizing, photogrammetry, and the use of existing digital data. The author discusses these methods and outlines where each works well, and any disadvantages that might exist as a result of their use. The discussion of existing digital data is particularly helpful to the manager who wants to make use of more readily available information.
Aronoff also surveys data output devices, including hardcopy (printers, plotters, etc.) and "softcopy" equipment (displays). The softcopy section includes a brief introduction of how displays work, including the concepts of raster and vector presentation.

Perhaps the most important (not necessarily the most interesting) chapter to any manager involved in planning a GIS is the chapter concerning data quality. This much-misunderstood issue is discussed from the viewpoint of data-error sources: individual data elements, the entire data set, and factors relating to data usage. This presentation is crucial for any manager intending to use GIS technology, and should be a key concern early in the project to insure strong data quality and integrity.

All GISs imply some form of data management, and Aronoff next discusses several methods currently in use. After defining data models, various database management techniques are defined and discussed, and examples are given from selected GIS product offerings. As with almost all of this book, the author's interesting examples help the reader to understand this complex topic.

The discussion of GIS analysis functions describes the basic capabilities that users generally require from a GIS. Performing analysis in a spatial database environment requires an understanding of the process involved, and Aronoff provides important definitions, methods, and uses for many of the most basic GIS analytical capabilities. Managers again will benefit from the examples when planning their systems.

Finally, Aronoff moves into the general topic of implementing a GIS. He discusses the common steps that most organizations go through, and breaks them down into phases that include many of the key issues in any implementation. Responsibilities of the project participants are discussed, and several points are made to help insure project success.

Throughout this book, Aronoff labor to keep the reader in focus. He does this by providing adequate information to create a successful GIS, without providing too much or too little detail. There were a few exceptions, however. Remote sensing, for example, was covered in more detail than necessary. While this section of the book provides interesting reading, the author's bias towards the topic is quite evident.

On the other hand, the discussion of database management was limited to current developments in artificial intelligence, and could have included a discussion of additional database management schemes that are available in the GIS marketplace. Managers will also find of interest the chapter dealing with GIS implementation, but the phasing of a project as shown simplifies many of the more difficult issues that arise during a typical project. While the steps form a good basis for implementation planning, the manager should understand that many of these phases can be more complex than they appear.

Despite these concerns about the book, I found it well-written and informative. As the book says, anyone managing such a project requires some knowledge in many areas and deep knowledge in a few. This book successfully provides much of the information needed to begin moving in the right direction. Managers who read and understand this material will be well on their way to overcoming the knowledge and terminology barriers that many of us face when establishing GIS technology in our organizations.

Andrew Zetlan is the principal consultant for The Excel Group, a consulting firm in the AM/FM-GIS field. He holds a B.A. in applied science and a B.S. in electrical engineering, both from Lehigh University, and an MBA from the University of Delaware. He has been the consultant on many projects that involve the planning and implementation of AM/FM-GIS systems.
SOFTWARE REVIEW

In Depth:
Tralaine Geocoordinate Converter

Reviewed by Joseph S. DeLotto and Greg Theisen

The Tralaine Geocoordinate Converter is a map projection program designed to perform coordinate conversion functions for users of PC-based geographic information systems (GIS) and other spatial-data handling programs. The program supports eight commercial file formats as well as user-specified formats, and converts coordinates during a file copy process (it does not do format conversions). Tralaine can perform forward and inverse conversions for four popular projections: Transverse Mercator, Lambert Conformal Conic, Albers Equal Area Conic, and Hotline Oblique Mercator. Along with the projections are parameters for the 60 UTM zones, 121 NAD-27 SPC zones, 100+ NAD-83 SPC zones, and a few special systems. The program also allows users to supply their own projection parameters, although it does not allow for definition of additional projections.

Also available from Mentor Software is a NAD-83 datum shift database containing conversion coefficients that allow Tralaine to convert from NAD-27 data to NAD-83 data. These data are available on a state, regional, or national basis, costing $100, $250, and $1000 respectively.

This review will consider only the merits of the Tralaine software (release 2.3—7/17/89), and not any aspects of the optional database.

Features

The proliferation of microcomputer software for functions such as CAD/CAM, geographic information systems, and automated mapping have made it easy to display and manipulate a variety of map data. However, many PC-based spatial-data handling packages do not include a broad range of map projection and coordinate transformation routines. These functions, long considered the esoteric realm of cartographers and geodesists, are now in great demand by professionals who are using geographically referenced data in a microcomputer environment. A need exists for software that can perform projection tasks for a broad spectrum of users, including surveyors linking local coordinates to larger systems, cartographers creating digital maps, and urban planners trying to standardize data from different sources. The Tralaine Geocoordinate Converter is one of several systems to be released in response to this newly created market.

The primary feature of Tralaine is its ability to handle a large number of commercial file formats as input. Supported formats include: Atlas™ MBI, USGS DLG-3 optional distribution format, ARC/INFO GEN, SEG-PL delimited text records (dBASE™ delim), fixed length records (dBASE™ SDF), and DXF. The characteristics of input file formats are easily specified through menu-guided prompts (Figure 1), which have optional choice lists and context-sensitive help facilities available through function keys. Selection of a supported format in the input menu automatically adjusts the output option to the correct parameters for file writing. All the user needs to do is enter the output file name. As the conversion takes place, a window is displayed showing the filenames, the from- and to-coordinate systems in the conversion, the format, and the percentage of the file that has been processed.

It is possible to create user-specified file formats by adjusting the generic file format “Fixed.” All standard format descriptions for Tralaine are kept in individual files in the Tralaine
An "escape to DOS" facility exists that lets the user go to the operating system and perform functions that require less than 200K of RAM, and then return by simply typing "exit."

As noted previously, Tralaine has four basic forward and inverse projections. In the release used for this review, there were 339 coordinate systems available for use that are defined by some parameter variation of the four projections. Among these 339 systems are several versions of Lat/Long (based on different datums), 60 UTM zones, over 200 State Plane Coordinate zones, and special systems such as Great Lakes Zones and Albers Equal Area parameters for maps of the entire 48 states.

New coordinate systems may be added and existing systems can be modified through the use of the Tralaine coordinate system editor. The CS editor allows the user to specify one of the four projections, a datum ellipsoid, the system unit, a scale reduction factor (cylindrical projections), a central meridian, mapping scale, reference parallels for conic projections Lat/Long origins, false eastings and northings, and coordinate pictures. The software also comes with 11 of the most common datum definitions, for both ellipse and sphere, as well as a datum editor that can be used to enter other datum definitions. Newly created coordinate systems and datums can be saved by Tralaine, and will appear in choice lists along with options that are already loaded on the system.

directory, and are distinguished by a .OPS suffix. While .OPS files exist for each format (e.g., dglfile.OPS, dxfile.OPS), only the Fixed format can be altered. Also referred to as SDF, or System Data Format, the Fixed format is composed of fixed-length records no larger than 3000 bytes. This .OPS file can be loaded into Tralaine through the standard "load settings" menu choice and, when the user specifies the input file information, a record editing menu is displayed to alter the format as needed. The user is able to specify byte sizes of header and data records, field sizes for data elements, and "coordinate pictures" for coordinate formats. The coordinate pictures are combinations of formatting characters that allow the user to interpret coordinate field data in a number of different formats.

The Tralaine menu interface has nine major function commands set up on a bar menu at the top of the screen, seven of which have sub-menus. At the bottom of the screen are 10 function-key definitions, including a context-sensitive help (F1) and a choice list (F2) that allows the user to see what options are available for various command line fields. The help menu option has textual descriptions for several topics, including software support, supported projections, defined coordinate systems, defined ellipsoid datums, coordinate pictures, and a description of Tralaine with the latest release notes. The context-sensitive help will document the current menu choice with textual descriptions straight out of the user manual.
Performance

The software was run on a 10 Mhz, 640K IBM PC AT with a math co-processor, 20 MB hard disk and monochrome display. With all the files loaded, the program and accompanying files occupy about 500K of disk space. The math co-processor is not necessary to run the software but is recommended. Tralaine does not have mouse support but moves through the menus with the help of arrow keys. Because the program is converting coordinates during a file copy process, RAM requirements are quite minimal. Users should ensure that adequate disk space is available for the transformed file, which in some cases may be upward of 4 to 5 MB. Tralaine can copy over original files, but that is usually a poor idea unless you have first backed up the data.

In terms of speed, we tested Tralaine by converting a 1 MB DLG3 file containing over 14,000 coordinate pairs from UTM Zone 17 to Lat/Long. The entire process was performed in over 10 minutes, which is not bad considering the computation involved. The help facility and choice list respond instantaneously, and the reading and writing of conversion parameters is also very quick. Essentially, there are no problems with the responsiveness of the system, but large coordinate transformations like the one described above may warrant a coffee break.

Somewhat disappointing to the reviewers was the fact that the user must specify the coordinate system of DLG3 files, rather than having the software read it from the file header. More troubling is that the coordinate system field in the file header was not changed during the conversion to indicate that the file has a new system. Mentor knows about this particular insensitivity, and may correct it in the next release. This type of problem does serve as a reminder about the nature of this type of conversion process. As Mentor states in their user manual for Tralaine, it is very easy to change a standard file format into something quite non-standard through selection of inappropriate coordinate transformation parameters.

One last performance note concerns the use of the [Control-break] key. While Tralaine states in on-line displays that [Control-break] will stop execution of a file conversion process, we found that rebooting with [Control-alt-del] is the only way to stop a conversion.

The performance, in terms of the functions available and their execution, is rated GOOD.

Documentation

Documentation for Tralaine consists of an 81-page user manual divided into two sections. The first section is a brief, poorly written introduction to the basic concepts of coordinate systems and map projections. The second section is a fairly well-organized discussion of how to use Tralaine. If you are already familiar with the basic concepts of cartesian coordinates and map projections, then you can proceed to the second section without fear of “missing” information. However, if you are not familiar with these concepts, we suggest that you find a source other than Tralaine’s documentation to use as an introduction. A couple of recommended sources include USGS Professional Paper 1395: “Map Projections—a Working Manual” by John Snyder, or a text such as Elements of Cartography by Robinson, Sale, Morrison, and Muehrcke (1984).

Problems with the first section are principally a matter of style and organization, although several matters of content are also questionable. For example, there are 12 figures in the first section. Few of these figures help the reader understand concepts being discussed, and none of the figures are directly referenced from the text. As a matter of content, there is an unequal assumption of technical knowledge made upon the reader. Some terms, such as “cartesian coordinates” are defined before they are used in the discussion, while other more technical jargon such as “GPS” and “remote sensing” are given to the reader without a word of explanation. All of this is added together in a profusion of awkwardly worded two-sentence paragraphs that will dismay even the most hardened reader of technical documentation.

The second section in the user manual is concerned with the use of the menu system. There is a brief description of the eight main menu options and the items available under each option. This part of the documentation makes good use of screen dumps and illustrations to show the user what response to
Ease of Learning

Tralaine comes with an installation program; however, it is necessary to follow along with the directions in the user’s manual. The install utility does not modify the system files and will require some editing by the user. Those familiar with DOS will find the installation procedure easy, while those unfamiliar may find the setup to be confusing. The user manual does not provide a tutorial; however, it does provide a detailed description of all the menu commands. Those familiar with basic map projection concepts will find using the package to be straightforward.

The program is menu driven and consistent throughout. There has been an attempt to follow some of the keyboard conventions used by other PC software packages. Use of this keyboard standardization makes the package feel familiar.

Ease of use is rated GOOD.

Ease of Use

The program is organized around a menu system. The main menu is well organized as are the options under each of these menus. If the purpose of a menu item is forgotten, on-line help will give a brief description of its function. An option key is unavailable to provide the possible choices and correct syntax for entering various parameters.

Ease of use is rated VERY GOOD.

Error Handling

This program appears to be well-tested; the authors were unable to cause the program to crash. The program will not allow inappropriate selections to be made from the menus. The output format is automatically set when the input format is selected. Possible selections can be viewed by the use of a function key or the help command can be invoked to better explain the selected command.

The original data file can not be overwritten without explicit instructions. The program does not check the file headers to determine if the selected projection is the actual projection of the data. It is up to the user to make sure this is correct. If an inaccurate format is selected, the program will give an appropriate warning.

Error handling is rated GOOD.

Support

Available as a menu item, the current support policy and telephone number are listed within the program. Technical support can be reached during normal business hours, and a phone service is willing to take down information anytime. The advice is free, but the telephone call is not, since they do not provide an 800 number. Mentor asks that, for obscure problems, data be provided so that they can duplicate your problem. They offer non-disclosure if necessary.

Mentor seems to be genuinely interested in incorporating useful ideas into future releases. They offer custom modifications to the software on a cost basis. Support is rated as VERY GOOD.

Value

Tralaine does what it claims to do, and in this respect we feel that it fills a valuable role in the spatial-data handling software market. If there is a caveat emptor to be offered about Tralaine, it would be in the form of a needs evaluation. Do you have data in a commercial file format and no other way of converting it to a standard coordinate system? If so, there is a good chance that Tralaine can perform the functions you need. The 339 coordinate systems represent more systems than most users need. Realistically, if you are working in a limited geographic area, you may only use four or five of the systems (double that if you want to pay extra for the NAD83 conversion coefficients). If you are responsible for national coverage, then you may use a great deal more. If the system you need is not already defined by Tralaine and uses one of the four available projections, then it can be created quite simply.

Some users will have a greater need for the software than others. We feel that surveyors will find Tralaine to be a useful tool because it allows for customized coordinate systems, as well as facilitating linkages to larger systems. Planners will find
it useful because it works with popular commercial file formats, and allows conversion to the most commonly used coordinate systems. As cartographers, we found it to be somewhat limiting because it only offered four projections. Tralaine is not a very good educational tool because it does not have built-in display capabilities. A user could, of course, transform data from one of the supported packages and display them there, but none of those packages are designed to accentuate geometric distortions (e.g., using Tissot's ellipses).

Other map projection packages for the DOS environment are The Microcomputer-based Automated Projection System (M.A.P.S.) from RDS Systems, The WORLD Projection and Mapping Program by Philip Voxland, and MicroComputer Automated Mapping (MicroCAM) by Scott Loomer. Tralaine is distinguished from these packages in that it is intended more for production work and less for educational purposes, hence the variety of input formats and lack of display capability. Functionally, it is distinguished from PC ARC/INFO and Atlas*Draw in that its only purpose is map projection transformations.

Considering the limited selection of available single-purpose conversion programs, Tralaine can fill a valuable role for knowledgeable users of PC-based geographic information systems.

Product Summary

Company: Mentor Software, Inc.
11534 Steele Street
Thornton, CO 80233-2449
(303) 252-9090
(800) 234-8649

List Price: A single user perpetual use license is $250.

Requires: IBM PC/XT/AT/PS-2 and most compatibles, running MSDOS release 2.0 or later. 640K RAM required, 500K hard disk space used.

Recommended: Math co-processor.
Pros: User interface and quantity of data input formats.
Cons: Documentation, limited number of projections, and limited error checking of transformation results.
Summary: A useful, flexible tool that performs a very specific function. It is probably most useful for standardization of data from different sources.

Final Score: GOOD.

Joseph S. Delotto is a GIS programmer with the Manchester Computing Center at the University of Manchester (U.K.). He has a master's degree in geography from the State University of New York at Buffalo, and is primarily interested in GIS algorithms and digital elevation modeling.

Greg Theisen is the staff cartographer in the Department of Geography at the State University of New York at Buffalo. His primary interests include map projection theory and mapping.
GUIDELINES FOR FEATURE MAP SUBMISSION

1. The focus of the map section is on the image itself. We will consider both color and black-and-white submissions. You may submit a complete map, an enlarged portion of a map, or both. The following criteria will be taken into account: visual quality of the map; amount and quality of information transmitted; and reproducibility of the map within the journal context.

2. We will accept printed maps or maps available in hard copy, provided they are clean and that you indicate the portion you wish to be published. Alternatively, we require glossy 8 × 10 color or black and white prints. Slides are acceptable but must be accompanied by a print. All submissions should be of high quality. This is especially important for computer-generated images, which can be difficult to reproduce.

3. Two to six double-spaced pages of text should discuss the map and its construction.

4. Include a separate page with the title, and author’s name and address. Also include, on this page, a two- or three-sentence biographical sketch summarizing the author’s professional positions, current affiliation, and research interests.

5. Any acknowledgement must be included at the end of the text under the heading: Acknowledgements. If your submission is a copyrighted image, please contact the map section editor to make special arrangements.

6. Submit map materials and text to the section editor:

   William J. Craig
   Center for Urban and Regional Affairs
   330 Humphrey Center
   University of Minnesota
   Minneapolis, MN 55455