GIS Design: A Hermeneutic View

Michael D. Gould

Abstract

Innumerable GIS project failures during the past two decades may in part be due to the implicit mental model carried by GIS designers, which is based on objectivist assumptions and a narrow view of scientific method. Hermeneutic methods may be a useful alternative which can realign the way the designer approaches the nontechnical tasks of user requirements analysis and conceptual database design. Several traditional human/geographic information communication models are discussed, and an alternative hermeneutic model is introduced. Examples of concrete application of hermeneutics to the GIS design process are presented, based on the writings of philosophers, human-computer interaction specialists, and geographers.

Introduction

> ...we must step back and examine the implicit understanding of design that guides technological development within our existing tradition of thought. Only by unconcealing that tradition and making explicit its assumptions can we open ourselves to alternatives and to new design possibilities...
>
> (Winograd and Flores, 1986, p. 5)

Following the broadest of definitions, we often speak of GIS in terms of a macroproject, in which case the concept of GIS design transcends software engineering to include a host of institutional, social, commercial, and political issues. One of the basic and most necessary components of GIS design is the user requirements, or functional, analysis (Calkins, 1983; NCGIA, 1990; Marble and Wilcox, 1991; Emery, 1991; Montgomery and Schuch, 1993), because each project is unique and each user has a distinct view of the system and the geographic information produced by it. User requirements analysis typically involves a GIS designer (a.k.a the analyst) who visits the potential user site, conducts a series of interviews, establishes rapport with several types of potential users, and observes the current tasks, data flow, and information products. Thus, from the designer's point of view, user requirements analysis provides the details necessary for a proper conceptual database design (Elmasri and Navathe, 1989; Laurini and Thompson, 1992). From the user's point of view, the requirements analysis—ideally—assures delivery of an information system optimized to his/her needs. In practice, however, there are three common analysis scenarios which can adversely affect the conceptual design process.

First, GIS software vendors lament that often user requirements analyses are not carried out at all (Dangermond, 1990), which increases the risk of system failure or user disappointment when implementation is supposedly complete. In this case, either the user organization has decided not to enlist "objective" consulting services for the design and implementation phases of the GIS project, or the chosen consultant has failed to properly execute this vital system design task. Second, the user requirements analysis is often carried out by a single hardware/software vendor, especially in monopolistic cases where the purchase decision is already made. This situation favors analyses which are more prescriptive and skewed than might otherwise be the case, because the analyst is constrained from the outset by his/her system's current capabilities and limitations. The situation is illustrated—unintentionally—by the comments of Leighton and Kutsal (1989):

> This [needs analysis] is the best opportunity for a vendor to educate clients with regards to technology and what is practical, and to study the client's operation... . During this phase, a vendor is being paid to be honest and forthright. This is an ideal opportunity to present the "reality" of a client's perceptions, and to correct misdirected or overstated expectations. (p. 378-9)

Third, even so-called "objective" user requirements analyses conducted by third-party analysts are necessarily subjective if the analysts are indeed human beings living within society. Furthermore, this article argues that certain system design methodologies may actually facilitate an analyst's pretension (or belief) of objectivity, which may lead to inaccurate, poorly representative requirements documentation because the user's view is not adequately considered. Perhaps the greatest misconception in the field of information systems design is that the entire process must be a well-controlled, objective, quantitative exercise when, in fact, one of the key components—user requirements analysis—involves the practice of social science. The latter is a field which has encountered problems with quantification and objectivism and, therefore, has explored alternative methodologies during several decades.

This article reviews what has been, since the 1970s, the "traditional" GIS design approach—structured system design—and it makes explicit some common assumptions of this approach. The aim is not to debunk structured design methodology but, rather, to offer an alternative view which might soften and improve it. Alternative views are necessary because certain key elements of the GIS design task are not objectively fixed and agreed upon between designers and users and, thus, are not adequately treated by structured methodology. This is becoming more noticeable as the GIS field evolves to incorporate users who are neither technical specialists nor spatial professionals, because these users often have special problems and needs. Although the characteristics of two styles of design are discussed briefly in this article, the primary focus is on the philosophy behind this dichotomy, on how the GIS designer should view the design process.

Photogrammetric Engineering & Remote Sensing,
Vol. 60, No. 9, September 1994, pp. 1105–1115.

0099-1112/94/6009-000$3.00/0
© 1994 American Society for Photogrammetry and Remote Sensing

Departamento de Geografía Humana, Universidad Complutense de Madrid, 28040 Madrid, Spain.

Hard and Soft Design Approaches

Information systems fail for many diverse reasons, but primary among these are that (1) the wrong problem is addressed because the correct one was not identified, and (2) the wide view of social and psychological factors is neglected (Flynn, 1992). Several system design approaches have appeared during the past decade in an attempt to minimize these failures, and these can be categorized as being "hard" or "soft" design approaches. Skimming through the GIS literature, however, one may be led to believe that the only design approach is the first: the functionalist, hard science approach (Waters, 1993). This is more generally termed "structured design methodology" (Yourdon, 1989) and it has dominated the information systems field during more than a decade (Crinnion, 1991) as a *de facto* standard.

Structured methodologies offer the designers a set of tools—data flow diagram, entity life history, data dictionary, etc.—with which to hard-code their objectives and to simplify their presentation to the user. The future user, who usually knows far less about the technical possibilities of the system, is presented with a draft design plan and is encouraged to cross-check the analyst's findings in structured walkthroughs and presentations (Crinnion, 1991). Thus, the user requirements analysis, which is supposed to extract the user's ideas, opinions, needs, aptitudes, etc. is, in some cases, only an explanation of the *correct* way to do things and an opportunity for the user to "sign-off" on a proposed design. Note from Leighton and Kutsal's quote, that "reality" is defined by the analyst rather than extracted from the user or jointly agreed upon.

Because structured methodology is assumed to be an objective procedure whereby the designer observes the current user situation and suggests the correct solution, it may actually obscure the designer's natural subjective behavior. While structured methods encourage user feedback, early and active user participation is not explicitly written into the process. User problems are to be worked out iteratively, just as "system errors will be patched in the next revision." If the system is deemed flawed, then the design proceeds iteratively in a process called stepwise refinement. The *prototyping* design methodology (see Eason, 1988; Crinnion, 1991; Dunn and Harrison, 1991; Peuquet and Bacastow, 1991) is an extreme example of stepwise refinement, whereby a limited working version of the system, presumed to be flawed, is given to the user community for feedback, which then guides further design iterations.

Prototyping is essentially a modification—adding a measure of social concern—to the traditional structured methodology, and is still considered a technical process (Waters, 1993). It has become commonplace for organizations to design and implement prototypes, or "pilot projects," due in part to conservative management practices and lack of confidence in the overall implementation plan. Organizations should be careful, however, not to fall into the trap of utilizing the pilot project as a substitute for rigorous initial system planning (Tomlinson, personal communication). For example, it is commonplace to utilize off-the-shelf GIS software for this prototyping effort, which can unduly bias the subsequent design process (Marble and Wilcox, 1991).

Alternatives to structured system design are often termed "soft" design approaches (Eason, 1988; Flynn, 1992). Flynn (1992) reviews such approaches, among them SSM and participative design. The first, Soft Systems Methodology (SSM) is due to the early work of Peter Checkland (1981). Its underlying theme is that reality is socially constructed by humans and is not a "given," and problems are viewed as fuzzy, not structured, and without apparent solutions (Flynn, 1992). During the design process, a "problem situation" is generated and analyzed, the product of which are so-called "rich pictures." Given this problem situation, a set of relevant systems is derived and then a conceptual model is developed. Then the user or user group is asked a series of questions to determine how well the conceptual model matches their original problem situation. SSM explicitly addresses the primary cause of information system failures: lack of proper problem identification.

Participative systems design, due to Mumford (1981), stresses involving the employees who will eventually use the system in the design process. It also focuses upon socio-technical issues: the interface between the tools and techniques of the system itself, and the social and ethical goals of the organization. The approach also stresses a group-based appraisal—using questionnaires and interviews—of the required system before considering the existing system. The participative design approach is the one which focuses most directly on institutional (employee-user) needs, desires, and job satisfaction goals.

Although it seems clear that soft system design approaches can offer a wider view of user requirements definition through user participation, it must be noted that neither soft nor hard methods have been empirically proven to be better at providing usable systems (Flynn, 1992). Flynn argues, however, that soft design approaches are more suited to design situations whereby both "requirements uncertainty" and "process uncertainty" are high. That is, for well-defined requirements and problems—cadastral or other inventory applications perhaps—linear, structured approaches may be best. When these attributes are not well fixed and agreed upon—as might be the case for so-called "scientific GIS" applications—soft design approaches may be best. This second GIS use type has been growing rapidly during the past decade.

Structured Thinking, Structured Design?

Adding structure to a design methodology may make it more objective in the sense of formalization and, thus, being more easily understood and replicated, but it does not guarantee that the human designer/analyst will behave objectively. Therefore, we must recognize subjectivity as a human attribute which is natural and which cannot be muted. Subjectivity on the part of the designer is not a negative attribute and it cannot be avoided because we all have our prejudices and tendencies, especially toward solutions which have worked well in the past. Regardless of whether the system designer is a vendor employee or an independent consultant, he or she does not work in a social and organizational vacuum and, thus, the design process cannot be considered totally objective. Structure implies ease of control and description, but does not guarantee arrival at the correct answer, especially when the user's side of the story has not been properly accounted for. We must recognize this fact, alongside the fact that many GIS projects have failed during the past two decades (Marble and Wilcox, 1991) partly due to poor requirements documentation (Calkins, 1983; Laurini and Thompson, 1992). The reader is asked to consider three key questions. Is there a relation between objectivist thinking and overly structured design methods? Is there a relation between structured methods and system failure? And does today's evolv-

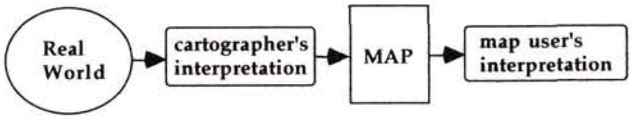

Figure 1. The traditional cartographic communication model.

ing GIS market demand that we pay more attention to alternative philosophical viewpoints which lead to alternative design approaches?

Mental Models and Design

User requirements analysis normally places considerable emphasis on desired geographic information products: the deliverables of an operational GIS. In the case of the city of Ottawa, for example, Tomlinson and his associates identified 100 unique geographic information products which might result from proper implementation of the GIS during a 10-year period (Smith and Tomlinson, 1992). This view of GIS design may be compared to an architect interviewing the future homeowner to get an idea of the basic attributes of the desired house and, thus, of the building products necessary to build such a house. In considering geographic information at this product level—in terms of some number of maps at a given scale—implementation details are de-emphasized so as not to skew the user needs documentation toward any one vendor solution (Montgomery and Schuch, 1993). In practice, however, this process is confounded by the designer's prior knowledge of the technical solutions available: he/she cannot wipe clean a well-developed mental model of similar information systems.

> Mental models let people derive appropriate behavior for situations that are not remembered (or never before encountered). People probably make up mental models for most things they do. This is why designers should provide users with appropriate models: when they are not supplied, people are likely to make up inappropriate ones.
>
> (Norman, 1988, p. 70)

The user begins the requirements analysis process with preconceived notions about how his/her GIS should "look and feel" and how it should perform: what is termed a mental model (Hearnshaw, 1990). Let us compare the user's mental model with the designer's. The designer's model is rich from the technical point of view because he/she has experienced several system design projects and has witnessed success and failure. The user's model is naive, in the general sense of the word, because he/she has not participated in previous design sessions. The user's model may be based not on specific software or machines, but rather on asking questions and receiving answers using geographic information. These answers may not correspond to known, concrete geographic products.

This article speculates that, when we are not specifically trying to build new mental models, we use default models derived from past experience, primarily from visual stimuli such as published diagrams, flow charts, or artistic caricatures. Thus, we hold mental models of abstract concepts which we have never really seen, such as Heaven (clouds), electricity (a continuous flow), gravity (Earth as a big magnet), the mind (a switchboard), etc. thanks to the imprint left by images in magazines, books, or on television. Again, this is speculation, but while it is not supported by empirical evidence, it seems to make sense as a working hypothesis.

Let us examine a concrete example of a mental model: how we view the assimilation of geographic information by an average person. Traditionally, the model was based on map use, and the relationship has been most saliently represented by the cartographic communication model (Figure 1), attributed to Robinson and Pechenik (1976). Variations of this model have been used by several authors (e.g., Bédard, 1987; Chrisman, 1987; Morehouse, 1989) to describe user/GIS communication, where reference to the map is replaced by GIS/LIS. In either case, the basic message, portrayed graphically as blocks connected by arrows, is that the real world is interpreted once by the cartographer/database designer—using well-known processes such as abstraction, simplification, and generalization—and then a second time by the user who reads into the abstracted cartographic image to extract necessary realism (Muercke, 1990). The model is based on a map reader/GIS user who is a passive receptor, not directly involved in the map-making process and, thus, having no explicit control over the information provided.

Why do we accept and rely on this model? First, because it is simple, which makes it easy to draw and to understand. Second, because it is compatible with our *de facto* definition of scientific method since the late 1950s: the application of positivism of one sort or another. The GIS community would be remiss not to acknowledge its entanglement, for better or worse, in this philosophical viewpoint. Positivism describes the view of science based on empirical measurement, explanation, and prediction of an objective "real world." It is also based on the scientist as disinterested observer, able to stand outside his subject matter (Johnston, 1983). The model in Figure 1 is compatible with that science: the real world is measured and described systematically—on paper or in a database—and then offered to the user. Although the cartographic communication model assumes iteratively testing each map with its intended audience, it does not suggest intimate user involvement before producing the first draft. If we implicitly accept this structured model of the relation between user and geographic information, then we also may be led to trust that the cartographer has objectively and disinterestedly designed the map. That is, after a literal reading of Figure 1, are we to assume that the cartographer has considered the user's needs before the first map was produced? The seasoned cartographer will know to "read between the lines" in Figure 1, and that the cartographic communication model has a long tradition—at least since Board (1967)—and is not as simplistic as it appears. But in the rapidly growing field of GIS, is today's average GIS designer likely a seasoned cartographer, or has he/she more likely only seen quick references to the model in articles such as Chrisman (1987)?

In the absence of alternative models, the GIS designer implicitly holds a mental model based on Figure 1, that GIS design is a value-free representation of the real world which is converted to digital form following structured, easy-to-follow guidelines. This design attitude may be further reinforced by similar linear mental models conjured up by published database design graphics such as in Figures 2 and 3. Each illustrates a direct path from reality through to physical database implementation and is based on early, "hard," *Life Cycle* design models which are partly to blame for innumerable system failures. These structured models of system

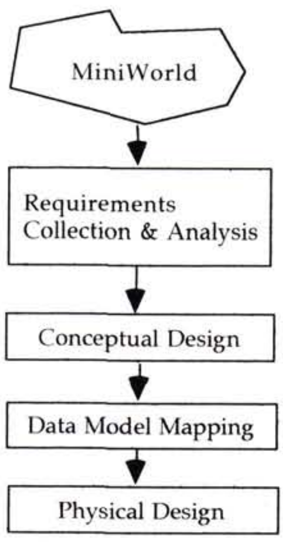

Figure 2. Phases of database design (after Elmasri and Navathe (1989), p. 38).

design were based on the elicitation of a set of user requirements, which was deemed as a straightforward, noncontroversial, technical exercise (Waters, 1993). Mowshowitz (1976) shows that in the early 1970s only 20 percent of information systems in North America achieved their intended benefit. Although a causal link between failure and design methodology used was never proven, we note that during that period of time linear and highly structured design processes were the norm. And while we know that GIS design during that epoch (for example, Calkins (1972)) followed such structured methodology, we see little published evidence that alternative design methodologies are being followed today (Waters, 1993). Modifications such as the Marble-Wilcox model (1991) cannot really be considered alternatives.

Incomplete Knowledge

Technical specialists often dominate the design team so that users are marginalized by the design process (Dunn and Harrison, 1991). Laurini and Thompson (1992) point out that users are often perceived as not knowing what they want, not being able to clearly articulate their needs, having needs which change over time, and not approaching the design task in the right way. This situation can be viewed in two ways: as a problem to be solved or as the naturally occurring situation which must be accommodated by the design process. The same dual viewpoint exists regarding subjectivity. In order for system design to fully account for user needs, the latter viewpoint must be adopted on both topics: the GIS designer must ask how his/her design methodology addresses these naturally occurring, inevitable phenomena. The typical user, who has recently had this new technology thrust upon him/her and has not experienced multiple user requirements analyses, cannot imagine how his/her work habits and organizational structure might change, and perhaps cannot list hypothetical novel geographic information products. The user is a system component which is really not subject to change, so the design process must adapt to the current state of that component.

The view that a user does not properly understand the design process is elitist and self-serving. The system designer should not confuse a user's incomplete knowledge with ignorance. If the user fails to immediately understand the workings of an information system or is unhappy with its design, then a common explanation is that he/she lacks necessary training. This lack of training, if true, should have been identified during the requirements analysis as a key contextual factor. If it was not noted in the initial requirements documentation, then it is only an excuse. And an obvious response is to provide a custom user interface which alleviates the need for specialized training. Many GIS users possess expert-level knowledge in the application field in which the GIS is to be utilized but have neither the time nor desire to learn the technical intricacies of a specific system. Then again, the user's overall goal should not be mastery of a new machine but, rather, more productive interaction with geographic information (Mark and Gould, 1991).

The system designer also possesses incomplete knowledge—regarding the user's environment, for example—and, thus, assumptions and stereotypes can be the cause of misunderstandings during the needs analysis. He/she may assume, for example, that the user will want to view planametric maps or use the leading relational database management system (RDBMS). Just as the analyst must be careful not to invite an important client to a steakhouse without first asking if he/she is vegetarian, the analyst needs to know how and when to leave the structured routine and to ask more personal and context-specific questions of the user. In light of the user's lack of experience in this area, the GIS designer has but two options: (1) continue to marginalize the user and carry on with the analysis, making key decisions on behalf of the user using past experience as a guide, or (2) realign his/her mental model to better accommodate the user's incomplete knowledge and special context.

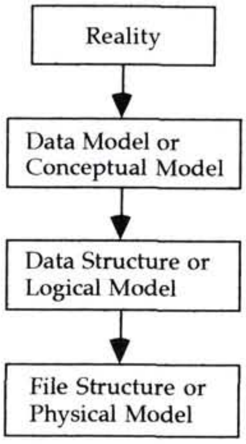

Figure 3. Reinterpretation of Peuquet's four levels of data abstraction (after Maguire and Dangermond (1991)).

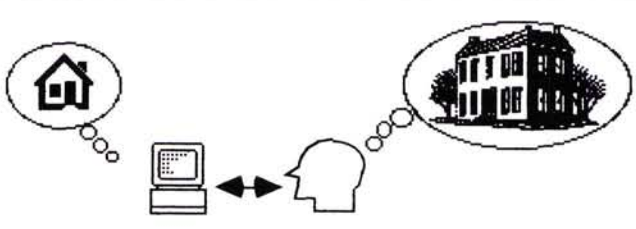

Figure 4. Communicating spatial information (after Kuhn (1990)).

Alternative Models

What is so wrong with the models portrayed in Figures 2 and 3? One problem is that the models illustrate a single pass and do not explicitly promote cycles of learning or user feedback, where the GIS user's mental model plays a role in the design or modification of the GIS. As a slight modification to these simple models, Medyckyj-Scott's graphic (1993, p. 91) includes a feedback loop to the "requirements" box, but only after implementation and testing have already been completed. Again, while we realize that the seasoned database designer will know to "read between the lines" and that these models really are not as simple as they appear, it must be stressed that in today's rapidly expanding GIS field we can make no assumptions about the background or knowledge of the players (Gould, 1991; Medyckyj-Scott, 1993).

Since the appearance of the linear models in Figures 1 through 3, several alternative models have been suggested. Kuhn's (1990) model of communicating spatial information (Figure 4) illustrates a dual viewpoint: the user's mental model of the phenomenon of interest as opposed to the computer model of the objects to be represented. Most important is that it places the user between these two views, neither of which is labeled "reality." The user requirements analysis must consider both views, just as the architect must consider both his technical view and the less precise (but very real) "look and feel" which characterizes the homeowner's view. The architect will not have satisfied the homeowner if the house is built using sound design and construction principles but does not make the homeowner comfortable and does not correspond to his/her prior mental model. Also note that the architect cannot easily ask that the unsatisfied homeowner "wait for fixes in the next version."

Institutional issues have been added to the communication model by several authors, logical in that GIS are developed for organizations more than for individuals. Marble and Wilcox (1991) mention the importance of these issues, as part of their modified structured approach, but they do not suggest what to do about them. Bédard (1987) speaks of the database "gatekeeping" function of a central LIS agency. The existing rules and regulations of such an institution will often obscure or minimize the effects of individual or group mental models about how the system should function. The result of the GIS/LIS design process is a database which reflects an "official" view of reality which binds all system users (Bédard, 1987). Thus, GIS designers who routinely deal with these institutions may be prone to assume that the individual user's opinion is of little importance in the conceptual design process. This assumption might be avoided by adoption of Bédard's communication model, which does not explicitly accommodate user feedback but does permit a pluralistic (consensus) view of the database, where individual user views are indeed considered.

Chrisman (1987) proposes a culturally based communication model, which he considers the institutional evolution of the cartographic communication model (see Figure 5).

Chrisman's cultural model differs conceptually and graphically from the linear models in Figures 1 through 3. The GIS designer who adopts this mental model of system design is encouraged to acknowledge, accept, and promote a feedback cycle between him/herself, the user, and the user's institution. Chrisman thoughtfully included two levels of feedback processes: data collection and socio-economic processes, labeled *a* and *b*, respectively, in Figure 5. Although the processes are not described in detail, we can read into the graphic two statements: (1) data collection should be carried out by personnel within the agencies involved, so that their own view of the world is considered, and (2) individual people have some influence over the practice of institutions but are sometimes subsumed by the institution.

Chrisman (1987) concurs with an earlier argument in this article, when he states that the first conclusion of his cultural argument is "... that geographic information is a human, social commodity. It is not strictly empirical and objective." (p. 1369) He then goes on to warn against the opposite extreme—pure relativism—where we lose touch of our common, cultural reference system.

Another user-sensitive system design model is that proposed by the ANSI-SPARC committee some two decades ago (see Date (1983) for details). Here, individual user views of the real world are accommodated at what is called the external data modeling level (see Figure 6).

The conceptual level, then, is seen as the "community view" (Date, 1983) or the "official view" (Bédard, 1987): the synthesis of all user views into a single conceptual database. It follows, therefore, that individual user views (mental models) of the GIS and its geographic information must be considered during initial conceptual database design if, in the course of system use, the user is to be able to extract his/her appropriate view from the database.

A minor improvement on the ANSI-SPARC model is a revised diagram by Frank and Mark (1991), which explicitly links the external schema of two user groups to both the conceptual and internal levels of abstraction (Figure 7). This connection, and the absence of directional arrows, permits an implicit feedback between the user's view and the overall

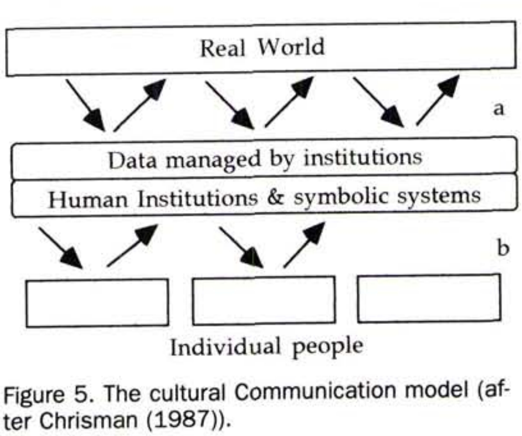

Figure 5. The cultural Communication model (after Chrisman (1987)).

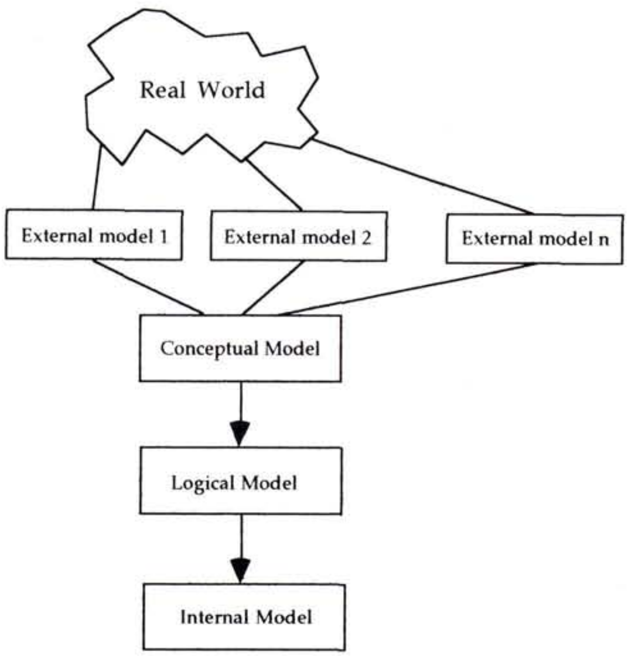

Figure 6. Interpretation of ANSI-SPARC data modeling levels (after Laurini and Thompson (1992)).

design and implementation of the database. This feedback supports the prototyping system design model, cited by Dunn and Harrison (1991) and Waters (1993) as a "third generation" design methodology, and could theoretically be extended to the approach suggested in this article.

The diagram by Frank and Mark also eliminates explicit reference to the so-called "real world," which seems misplaced in any model which permits true user-specific views. These individual views should be based not on a single, preconceived real world, but rather on *n* context-dependent real worlds for *n* users or user groups. This is not to say that we therefore have fallen into the relativism Chrisman warned us of: we still retain the overall, common structure of the conceptual view, and the experience which all humans share. Thus, the conceptual level is our "shared real world." To Frank and Mark (1991), this means negation of certain objectivist ideas, and adherence to the newly developed philosophy of experiential realism (see Mark, 1989). In this article, however, we suggest an example of what Waters (1993) labels the "fifth generation" of system design, which "drew strength from the phenomenological and hermeneutic traditions" (p. 64).

A Hermeneutic View

This article has discussed several views on the relation between user and geographic information, as well as some common models used to represent that relation within the conceptual design process. Mark and Gould (1991) highlighted an alternative view—from the perspective of user interface design—where computer use is de-emphasized in favor of direct use of geographic information, and, thus, focus is placed on the external (user) level of system design. Their commentary has been cited frequently in recent literature (e.g., Nyerges, 1993; Egenhofer and Herring, 1993; Ganter and Crane, 1993) but such citation is for the most part gratuitous, aimed at demonstrating that GIS user interface research is underway. Mark and Gould's deeper message, aimed more at conceptual design principles than at the exposition of user interface alternatives, is encapsulated by the following points:

- The prime objective should be to enhance user interaction with *geographic information* and with *geographic problem-solving*, rather than with software or hardware (p. 1427);
- Much of the "user interface problem" is not a programming problem, but rather a conceptual and a human problem (p. 1429);
- Underlying the design of GIS are questions such as, "What do people do [with or without computers]?" and, more specifically, "What do GIS users do?" (p. 1429).

Mark and Gould referred superficially to the work of Winograd and Flores (1986), but they failed to duly publicize its central message: the hermeneutic system design alternative. Here, the following section gives a brief introduction to the concept of hermeneutics and then suggests a hermeneutic model which may be used to substitute or augment structured design models. This hermeneutic model, or view of system design, may serve to create a more user-centered mental model among GIS designers.

Hermeneutics

There are several philosophies of science available to us, and we will look briefly at three. Positivism, described earlier, assumes a context-free, objective study of the external world. This is the philosophy of science most commonly held by geographers involved in GIS-related activities and, judging by contributions to this journal, it is dominant in fields outside of geography as well. Structuralism, pioneered by Lévi-Strauss and Piaget and upon which many current cognitive studies rest, is based on theorizing and deriving abstract models rather than on empirical studies. Let us look at hypothetical examples of each approach. The GIS researcher who uses satellite imagery to "prove" that defoliation in a particular zone is positively correlated with nearby toxic effluents is practicing positivism. The approach can be identified by its use of objectively defined boundaries and classifications, and quantitative methods of hypothesis testing. The GIS researcher who attempts to define—as an intellectual exercise—the mental model people use to define fuzzy

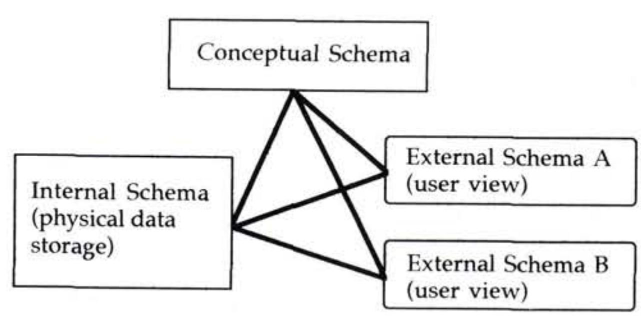

Figure 7. Relations between three ANSI-SPARC levels of abstractions, for user groups A and B (after Frank and Mark (1991)).

geographical entities, such as regions, in order to be able to implement these entities as objects in the database, is practicing structuralism. This approach can be identified by its lack of empirical testing; the researcher theorizes that a certain mental or behavioral structure exists based on intellectual reasoning and on anecdotal evidence. Both these approaches assume that the researcher is on the outside looking in, a disconnected observer of the phenomenon of interest.

A third possible approach is the hermeneutic approach: inquiry based on constrained subjective interpretation rather than objective explanation. Hermeneutics (from the Greek, *to interpret*) is defined by Packer (1985) as "an attempt to describe and study meaningful human phenomena ... based on practical understanding" (p. 1082), which implies getting behind the social and historical context of the subject (the writer, the politician, the computer programmer, etc.). Alternatively, we might view hermeneutics as the application of phenomenology: a post-positivist philosophy which examines the foundations of experience and action. Phenomenology seeks original context, to disclose the world as it shows itself before scientific inquiry, as that which is pregiven or presupposed by the sciences (Pickles, 1985). Thus, it focuses on the contextual background which normal (positivist) science conveniently assumes away or ignores in an effort to conduct a controlled study.

But let us not become lost in abstract definitions of hermeneutics, which is meant to be based on practical interpretation. Thus, to contrast the earlier applications of positivism and structuralism, we can state that the GIS researcher who conducts interviews of potential system users, to learn more about their view of the application domain and their prior experience, is practicing hermeneutics. To be even more faithful to the principles of hermeneutics, the researcher (designer/analyst) at the same time would make explicit notes regarding his/her own prior experience or context, which will affect his/her interpretation of the users' comments. These introspective notes are essentially *metadata*, and can be just as important to the user requirements documentation as metadata are to the fidelity of a spatial database.

A key to hermeneutics, noted here by two geographers, is the explicit acknowledgment that context is inescapable.

> Hermeneutics: awareness of cultural biases in the design of research as well as in the conclusions derived from them has led to debates over ideology, knowledge, and power, or, of some, acknowledgments of the hermeneutic circle. The researcher has begun to acknowledge his/her role as participant rather than observer of reality. (Buttimer, 1990, 24)
>
> The dialogue ... both enriches the analyst's understanding and enables the subject to divulge meanings; the analyst learns to live the life of the subject by participating in his language. Hermeneutics, then, is basically an empirical science, in that it seeks to explicate meanings at the phenomenal level and does not seek universal truths lying beneath those meanings. (Johnston, 1983, 61)

Extrapolating from the first quote, the analyst must recognize that the Heisenberg principle applies to his/her participation in the user requirements analysis. That is, the analyst cannot be, at the same time, covert observer and director of the analysis. And if he/she is in fact directing the analysis, then his/her opinion, tendencies, and even race, sex, age, etc., may filter through and have some effect on the process. According to the second quote, it is not enough that the analyst pay a quick visit to the user site: he/she must get intimately involved in the users' context and learn their language. Marble and Wilcox (1991), proponents of structured methodology, say of the GIS designer (analyst) that "it is valuable to have a "neutral" leader of the design process—one who does not have to overcome a history of interactions with other participants." According to the hermeneutic approach, it is precisely this disconnectedness that we are trying to avoid in the socially based user requirements analysis.

Hermeneutics stresses the empirical observation of true behavior, not the simulation of that behavior or a report of what that behavior usually is like. Furthermore, it is based on the view that this behavior—thoughts, speech acts, judgments—is necessarily based on interpretation and not on the disconnected observation of objective facts. Further details on hermeneutics in general, and on its role in the social sciences, can be found in Bauman (1978), Bernstein (1983), Bleicher (1980), and Gadamer (1976).

Precedents

Although there are no known direct references to hermeneutic analysis in the GIS literature, there do exist a few key precedents within the geographic and human-computer interaction literatures, and an indirect reference in the field of GIS. It should also be noted that to a great extent GIS is not all that different from general information systems. Two published works are especially important to the context of GIS design: Winograd and Flores (1986) and Turk (1990). The first is a widely cited book on cognition and the design of computer systems, which is different from others in the field of human-computer interaction (HCI) because it is firmly rooted in hermeneutics. Not only do Winograd and Flores support the use of hermeneutics as an empirical method for understanding human action (e.g., what people *do* with computers), their entire thesis is based on hermeneutic method and its base philosophy. (See the quote at the beginning of this article.)

Turk (1990) is the most comprehensive review article to date on the variety of perspectives and methodologies available to HCI research aimed at GIS design. Turk has a background in philosophy—in addition to his specialty of surveying—and he too cites the importance of the hermeneutic paradigm, especially the work of Heidegger (1962).

A significant minority of geographers has also promoted hermeneutic ideas. A salient example is the work on the relation between phenomenology and science by Pickles (1985), and then his later admonishment of the GIS community for being essentially blind to philosophies which are non-positivist in nature (Pickles, 1993). In that same publication, Sheppard (1993) attempts to demonstrate how so-called "Automated Geography" is not at all philosophically neutral, and how its reliance on hypothesis testing, secondary data processing, and Boolean logic lend it implicitly biased toward a singular view of science. Of his philosophical alternatives, Sheppard cites "Interpretative approaches ... [which] emphasize the difficulty of both determining the significant aspects of geographical phenomena and placing a definitive interpretation on them." Another well-known geographer, Peter Gould (1988), in an essay critical of the mechanistic cognitive studies which intend to inform GIS design, states,

> ... the texts [maps, other symbolic systems] are inanimate things without meaning unless interpreted and given meaning from a wholly human hermeneutic perspective... . Pointing to the human act of interpretation giving meaning to a text simply reinforces the importance of a statement and conclusion ... every

> text-creation, and every meaning-giving interpretation, is *context dependent.*

Gould is not attacking GIS *per se* but, rather, the poorly conceived approaches to their design, and he puts his finger on a key aspect of hermeneutics: context. Finally, it should be noted that Waters' (1993) one-page column entitled "GIS: Paradigms Lost" is an important contribution to the debate on alternative GIS design methodologies (paradigms). As mentioned earlier, his "fifth generation" of system design corresponds to the hermeneutic method. Waters also provides a fruitful "pointer" to the extensive work of Hirshheim and Klein (1992) on the topic of information system design paradigms.

Evidence of the diffusion of Winograd and Flores' hermeneutic ideas (or perhaps of Heidegger's original work) is the work of HCI researchers (and Digital Equipment Corp. employees) Whiteside and Wixon (1987). We quote from their suggestions to HCI researchers:

> We invite the authors [readers] to observe some people doing some real work and to try to do this with as few theoretical preconceptions as possible, following a hermeneutic approach. (p. 357)

and from their section entitled "Consider interpretation a viable alternative to explanation or modeling":

> [Model-based HCI] ... has elements that are assumed to have meaning independent of the context in which they occur... . Formal modeling seeks explanation in terms of a supposed underlying true structure. Interpretation seeks a more relative truth, one that is sensible and appropriate to the situation at hand, but not absolute or timeless. Thus, interpretation is much more contextually dependent than formal modeling. **Practical design, however, is exactly the creation of things that will work well in a specific context.** (p. 361, emphasis added)

The Shared, Social World

Hermeneutics is based on the experienced or shared world, not pure relativism whereby the real world exists only in the minds of individuals. It is based on everyday practice, not everyday concepts; on what people actually do and not what they *say* they do or are hypothesized to do. This is the very core of Heidegger's philosophy (Heidegger, 1962; Dreyfus and Hall, 1992). There are certain events that we cannot pretend are personal, such as walking on the ground and breathing air: these are both experienced and shared. That these events are due to gravitational attraction is a theory, not a fact of our experienced world. That people share similar experiences—both cognitive and bodily—is one of the keys to hermeneutics. According to Heidegger, "meaning is fundamentally social and cannot be reduced to the meaning-giving activity of individual subjects" (*cf.* Winograd and Flores, 1986, p. 33). Applying this to our design task, the shared world concept is what makes possible the conceptual level of GIS database design (see Figure 6), which cannot, by definition, allow the coexistence of n relativistic external models for *n* users. It is necessarily the synthesis of all these.

Because of the assumption of this social, shared world, hermeneutics is circular (Buttimer, above, mentions the "hermeneutic circle"), so as the analyst tries to get at the underlying context of his/her subjects, he/she becomes immersed in his/her own context and in the context of the local work environment, which shapes and colors the way he/she will interpret the comments of future subjects. This is an iterative structure that we should not attempt to hide or eliminate, as it is inevitable. Instead of treating this circle of prejudice (or pre-understanding) as a fault of the analysis, we should openly recognize it and make it explicit (i.e., write it down and include it in the user requirements document). We highlight this circular characteristic in an effort to demonstrate that, simply by considering hermeneutics in our user requirements analysis, we have already completed one iteration, and are already are *doing* hermeneutics. That is, by considering hermeneutic inquiry, we are questioning our prejudices and the possibility of one single, objective explanation of the real world. A hermeneutic attitude toward the design process may reduce the tendency to dictate norms or prescribe, and may increase the tendency to explore, question, and admit the prejudicial aspects of the user requirements analysis. At a more idealist level, hermeneutics encourages a more truthful, ethical user requirements analysis.

Thrownness

Winograd and Flores (1986) describe in some detail several key aspects of Heidegger's philosophy—and, thus, hermeneutics—which can be applied to system design. Two of the most applicable are *breakdown* and *thrownness*. The former, explained by Mark and Gould (1991) in the context of GIS user interface design, is a situation which suddenly makes the previously unconscious use of a tool very conscious. This would be the case when we are approaching a stop sign and suddenly find that our car's brake pedal does not function, or when the GIS user must leave his/her problem-solving mode to attend to a UNIX system error.

Thrownness—an awkward term due to imprecise translation from the German—is essentially Heidegger's explanation of non-rationalistic behavior. Winograd and Flores explain that they deliberately use the term *rationalistic* rather than rational because, while they do not defend irrational behavior, they do wish to highlight certain aspects of rationalist thinking which leads to not very rational behavior when viewed in a broader perspective. The rationalist decision-making model (according to Winograd and Flores, 1986, p. 20), such as promoted by Simon and his colleagues (Simon, 1976), assumes a person rationally chooses from among concrete alternatives following a series of steps:

- List the alternative strategies,
- Determine the consequences of each strategy, and
- Comparatively evaluate each set of consequences.

This rationalistic model nicely matches the methods used in structured system design. In the practical world, however, we find that the rationalistic model does not conform to what we observe in the daily workplace. The workplace demonstrates an intractability which Simon's model does not accommodate, and this can adversely affect our user requirements analysis. The real world is not so well-defined and structured as we would like it to be. We return to the experience of HCI researchers Whiteside and Wixon (1987), who indicate that the basic assumptions of certain quantitative user studies (i.e., goal-oriented, rationalistic behavior) may be fundamentally flawed and, thus, inappropriate for studying the behavior of interest. This is supported by their considerable time spent observing users in natural environments:

> The discussion of goals and goal-oriented behavior ... does not capture what we have observed in the field or the lab, in our studies and observations of users. In a tightly defined, carefully controlled laboratory situation, where the user has been given a set task, goals are perhaps identifiable. However, in a more rep-

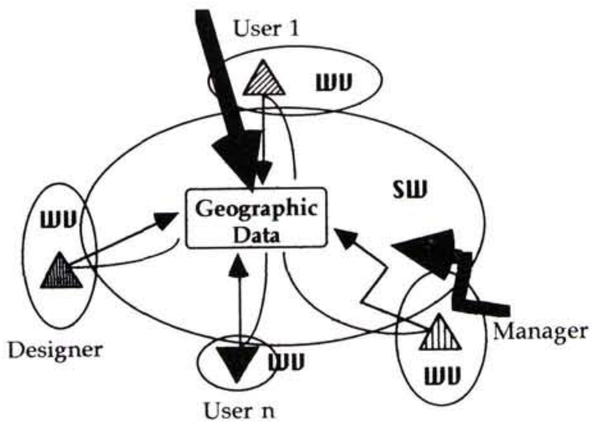

Figure 8. An attempt to preserve the fidelity of two "user views," of User 1 and the Manager.

> resentative situation, users are often unable to state unambiguous conditions of satisfaction, and are dependent on the context in which they are operating. (p. 359)

Heidegger proposes that we are often *thrown* into situations, where the possibility to step back and objectively weigh our options does not exist. A good example is again the use of the car's brake pedal. When we are driving rapidly and suddenly a dog runs in front of the car, we are thrown into action, and are not permitted any sort of removed contemplation. There is no time to weigh the options or form a new mental model of the situation. Winograd and Flores (1986, pp. 34–35) list several characteristics of thrownness that we can apply directly to the user requirements analysis situation.

- "You cannot step back and reflect on your actions": the user is not able to leave his/her shoes and objectively analyze his/her needs;
- "The effects of actions cannot be predicted": the user often cannot predict the requirements and the deliverables of a yet-unimplemented GIS, especially if he/she is not presently using another GIS;
- "You do not have a stable representation of the situation": the user cannot have a stable representation of his/her needs, because (1) there will exist fragmentary and conflicting information and (2) the user may be confronting occupational changes as a result of the GIS implementation; and
- "Every representation is an interpretation": there exists no single representation of the work environment and the user's needs, only interpretations. Therefore, the analyst should be asking the user for his/her impressions, ideas, and reactions rather than asking objective "What is...?" questions.

Whiteside and Wixon (1987) make direct reference to thrownness, as an alternative to rationalistic assumptions:

> We suggest, as a possibility, an alternative assumption: Users do not start with goals at all; rather, they are always already acting in a situation, thrown to it as it were, unreflectively and unanalytically. (p. 360)

Furthermore, they believe that often a subject will "invent" a goal, *post hoc*, if asked by a researcher to list one. The GIS designer should be wary of users inventing goals or needs, so as to satisfy a rigid analysis procedure.

A Hermeneutic Graphic

This article speculated earlier that simple graphics can become default mental models for GIS designers who otherwise have not explicitly formed a model of the design process. If this is the case, then our hermeneutic alternative needs to provide a simple graphic for this purpose. Figure 8 represents one such attempt.

A detailed description of Figure 8 is in order. Each participant in this GIS design process—designer, manager, and *n* users—has his/her world view (WV). This WV is conceptually isomorphous with the external level as defined by ANSI-SPARC, and contains intellectual, philosophical, experimental, and social components of the person's daily experience. The WV ellipse is not isomorphous across human subjects; however; some people have a wider range of social, intellectual, and cultural skills, due mainly to increased experience in a complex shared world. This shared world (SW) is represented by the large, central ellipse, and is isomorphous with the conceptual level of the ANSI-SPARC definition. Each of the arrows represents a view of the geographic data available. This view need not be assumed straight and unobstructed, as seen in the case of the manager in Figure 8, and the surface across which we view the data is nonisotropic. The manager's view, for example, is necessarily complicated by metadata concerns such as data cost and quality, whereas the ordinary user's view is more simply content-oriented. The arcs alongside each arrow represent what we have termed feedback loops. In this hermeneutic model these return paths represent, more concretely, the flow of geographic information. This allows for various cycles whereby a user visualizes and manages geographic data (bases) and gradually builds more and varied interpretations of geographic information. That is, the user's view is not static and is permitted to evolve. When the user requirements analyst probes the potential user, this mental model reminds him/her to consider not only the person's view of the data, but also how the interpretation and use of those data affects the user's work. A user requirements analysis may need to reiterate several times per user (or user group) before proceeding to the next world view (WV).

The analyst must take special care with treatment of the shared world (SW). Traditional user requirements analysis, based on an objective model, would be represented by a heavy arrow which does not cross any one user's world view. This is akin to proceeding straight to the conceptual database design without considering specific user input.

Adherence to this model would help guarantee that the conceptual database design truly reflects both personal views and shared-world "realities." Doing so should improve the possibility of designing a GIS which, when queried by a particular user, is able to produce geographic information which is both locally and globally relevant and useful. Finally, we stress that the model does not emphasize either a strictly subjective or objective focus on the design process, but rather, a socially mediated compromise.

Conclusion

Goodchild (1992) proposes that we look beyond GIS's technical considerations to consider a geographic information *science*, and he questions "the extent to which GIS as a field contain a legitimate set of scientific questions and the extent to which they can be expressed ... ." (p. 32). But, in order to identify the full range of these questions, the GIS community will need to exercise a fundamental but unused muscle: organized skepticism. The basis of arguments such as those of

Pickles (1993) and Sheppard (1993) is not that positivist science and related work is all wrong, but rather that GIS rambles along, blind to the alternatives which other "scientists" considered long ago. While their thought-provoking arguments come from outside the walls, the core GIS community lacks a serious self-critical element. Critiques such as that by Aangeenbrug (1991) are really only software wish lists, and do not touch upon the deeper issues a fledgling field must confront before it can begin calling itself a science.

This article does not intend to promote hermeneutics as an outright substitute to normal scientific method and structured design. What it does aim to point out, however, is that certain key elements of the GIS design process, such as user requirements analysis and conceptual database design, are not agreed upon and easily quantifiable. Thus, they do not necessarily need to follow the same paradigm as more fixed, technical aspects of system design. The elements in question are based on social science research, on interviewing people and interpreting and understanding what they have to contribute, and on the non-rationalistic situations in which these people sometimes operate.

It is hoped that the practical nature of hermeneutics has been transmitted by this article, and that the reader is not left thinking it is hopelessly transcendental or inapplicable. (Perhaps industry practitioners will need to rename the approach so that it sounds less academic!) Hermeneutics is not a cookbook of hard rules to be followed; however, it can be a fresh perspective on the problematic of GIS design, a perspective which can be applied to the way we work. Based on the above discussion of a hermeneutic GIS design model, we can summarize recommendations for GIS designers in the following items:

- Our human/geographic information communication model—implicit as a mental model or explicitly drawn on paper—should accommodate multiple external views and feedback cycles for each user or user group;
- The person (or team) conducting the user requirements analysis is always an intrusive participant in that analysis, not a disinterested observer, and the requirements documentation should reflect this;
- The hermeneutic design model encourages the analyst to focus on the task of interpretation, not explanation based on pre-established norms;
- User requirements analysis based on a user's rationalistic, objective behavior may be counter-productive and misguided, as he/she is often thrown into complex situations which are difficult to describe;
- This lack of ability to precisely describe his/her situation is not cause for the analyst to abandon the user's input but, rather, a signal that another cycle of interpretation may be necessary;
- Designers should familiarize themselves with Winograd and Flores (1986), as perhaps the most succinct, readable, and relevant treatment of hermeneutics available; and
- Simply becoming aware (through Winograd and Flores) of the existence of hermeneutic alternatives to objectivist thinking signifies a first, basic application of hermeneutics. This is because, by comparing the two philosophical approaches, the reader is forced to question his/her presuppositions as an objectivist thinker (or analyst). Identifying his/her inherent context (and prejudices) is a first pass in the hermeneutic circle.

Acknowledgments

Many of the system design graphics in this article were encountered in the work of Nunes (1992). David Mark and Barbara Buttenfield provided encouragement in the pursuit of this topic. Literature review for this article was carried out as part of Research Initiative 13 of the NCGIA, supported by the National Science Foundation (SES-88-10917). Two anonymous reviewers provided very useful comments on an earlier draft.

References

Aangeenbrug, R., 1991. Critique of GIS, *Geographical Information Systems: Principles and Applications* (D. Maguire, D. Rhind, and M. Goodchild, editors), Longman Scientific, Essex, pp. 101–107.

Bauman, Z., 1978. *Hermeneutics and Social Science*, Columbia University Press, New York.

Bédard, Y., 1987. Uncertainties in Land Information Systems Databases, *Eighth International Symposium on Computer-Assisted Cartography* (Auto-Carto 8), Baltimore, pp. 175–184.

Bernstein, R.J., 1983. *Beyond Objectivism and Realism: Science, Hermeneutics and Praxis*, Basil Blackwell, Oxford.

Bleicher, J., 1980. *Contemporary Hermeneutics: Hermeneutics as Method, Philosophy and Critique*, Routledge and Paul Keegan, London.

Board, C., 1967. Maps as Models, *Models in Geography* (R. Chorley and P. Haggett, editors), London, Methuen, pp. 671–725.

Buttimer, A., 1990. Geography, Humanism, and Global Concern, *Annals of the Association of American Geographers*, 80:1–33.

Calkins, H.W., 1972. *An Information System and Monitoring Framework for Plan Implementation and the Continuing Planning Process*, Ph.D. dissertation, Department of Civil Engineering, University of Washington.

———, 1983. A Pragmatic Approach to Geographic Information System Design, *Design and Implementation of Computer-Based Geographic Information Systems* (D. Peuquet and J. O'Callaghan, editors), IGU Commission on Geographical Data Sensing and Processing, Amherst, N.Y.

Checkland, P., 1981. *Systems Thinking, Systems Practice*, Wiley, Chichester.

Checkland, P., and J. Scholes, 1990. *Soft Systems Methodology in Action*, Wiley, Chichester.

Chrisman, N.R., 1987. Design of Geographic Information Systems based on Social and Cultural Goals, *Photogrammetric Engineering & Remote Sensing*, 53:1367–1370.

Crinnion, J., 1991. *Evolutionary Systems Development: A Practical Guide to the Use of Prototyping within a Structured Systems Methodology*, Pitman Publishing, London.

Dangermond, J., 1990. How to Cope with GIS in your Organization, *Geographical Information Systems for Urban and Regional Planning* (H. J. Sholten and J. C. H. Stillwell, editors), Kluwer, Dordrecht, pp. 203–211.

Date, C.J., 1983. *An Introduction to Database Systems*, Vol. 2, Addison Wesley, Reading.

Dreyfus, H., and H. Hall (editors), 1992. *Heidegger: A Critical Reader*, Basil Blackwell, Cambridge, Mass.

Dunn, R., and Harrison, A., 1991. Assessing User Requirements for GIS—the Critical Stage in Implementation: How Prototyping can Help you Get it Right, *Proceedings, Conference of the Association of Geographic Information (AGI)*, Birmingham, pp. 1.12.1–1.12.4.

Eason, K.D., 1988. *Information Technology and Organisational Change*, Taylor & Francis, London.

Egenhofer, M.J., and J.R. Herring, 1993. Querying a Geographical Information System, *Human Factors in Geographical Information Systems* (D. Medyckyj-Scott and H. Hearnshaw, editors), Belhaven, London, pp. 124–135.

Elmasri, R., and S.B. Navathe, 1989. *Fundamentals of Database Systems*, Addison Wesley, Reading.

Emery, H.A., 1991. A Cookbook Approach to AM/FM/GIS Project Development, *Proceedings, GIS/LIS 91*, Atlanta, pp. 912–916.

Flynn, D.J., 1992. *Information Systems Requirements: Determination and Analysis*, McGraw-Hill, London.

Frank. A.U., and D.M. Mark, 1991. Language Issues for Geographical Information Systems, *Geographical Information Systems: Principles and Applications* (D. Maguire, D. Rhind, and M. Goodchild, editors), Longman Scientific, Essex, pp. 227–237.

Gadamer, H.-G., 1976. *Philosophical Hermeneutics* (translation), University of California Press, Berkeley.

Ganter, J.H., and T.E. Crane, 1993. Calculator: A GIS Control Panel for Extent, Scale, and Size Manipulation, *Proceedings, Eleventh International Symposium on Computer-Assisted Cartography* (Auto-Carto 11), Minneapolis, pp. 176–186.

Goodchild, M.F., 1992. Geographic Information Science, *International Journal of Geographical Information Systems* 6:31–45.

Gould, M.D., 1991. The GIS User: Make no Assumptions, *Proceedings, Eleventh Annual ESRI User Conference*, Palm Springs, California, pp. 519–523.

Gould, P., 1988. Geographical Information Systems, Cognitive Science and Linguistics: Reflections on Connections, *Report on a Miniconference: Cognitive and Linguistic Aspects of Geographic Space* (D.M. Mark, editor), 11-12 June 1988, State University of New York at Buffalo.

Hearnshaw, H.M., 1990. What is the User's Mental Model of a GIS? *Proceedings, European Conference on Geographical information Systems* (EGIS), Munich, pp. 427–436.

Heidegger, M., 1962. *Being and Time* (translation), Harper & Row, New York.

Hirshheim, R., and H.K. Klein, 1992. Paradigmatic Influences on Information Systems Development Methodologies: Evolution and Conceptual Advances, *Advances in Computers*, 34:293–392.

Johnston, R.J., 1983. *Philosophy and Human Geography*, Edward Arnold, London.

Johnston, R.J., D. Gregory, and D.M. Smith (editors), 1986. *The Dictionary of Human Geography*, 2nd Ed., Basil Blackwell, Oxford.

Kuhn, W., 1990. Editing Spatial Relations, *Proceedings, Fourth International Symposium on Spatial Data Handling*, Zurich, pp. 423–432.

Laurini, R., and D. Thompson, 1992. *Fundamentals of Spatial Information Systems*, Academic Press, London.

Leighton, D.H., and M.D. Kutsal, 1989. Service Delivery in GIS & AM/FM Systems for the Nineties, *Proceedings, GIS/LIS 89*, Orlando, pp. 374–380.

Maguire, D.J., and J. Dangermond, 1991. The Functionality of GIS, *Geographical Information Systems: Principles and Applications* (D. Maguire, D. Rhind, and M. Goodchild, editors), Longman Scientific, Essex.

Marble, D.F., and D.L. Wilcox, 1991. Measure Twice—Cut Once: A Structured Approach to Successful GIS Design and Implementation, *Proceedings, Eleventh ESRI User Conference*, Palm Springs, California, pp. 585–596.

Mark, D.M., 1989. Cognitive Image-Schemata for Geographic Information: Relations to User Views and GIS Interfaces, *Proceedings, GIS/LIS '89*, Orlando, pp. 551-560.

Mark, D.M., and M.D. Gould, 1991. Interacting with Geographic Information: A Commentary, *Photogrammetric Engineering & Remote Sensing*, 57:1427–1430.

Medyckyj-Scott, D., 1993. Designing Geographical Information Systems for Use, *Human Factors in Geographical Information Systems* (D. Medyckyj-Scott and H. Hearnshaw, editors), Belhaven, London, pp. 87–100.

Montgomery, G., and H. Schuch, 1993. *GIS Data Conversion Handbook*, GIS World, Ft. Collins, Colorado.

Morehouse, S., 1989. The Architecture of ARC/INFO, *Proceedings, International Symposium on Computer-Assisted Cartography* (Auto-Carto 9), Baltimore, pp. 266–277.

Mowshowitz, A., 1976. *The Conquest of Will: Information Processing in Human Affairs*, Addison Wesley, Reading.

Muercke, P.C., 1990. Cartography and Geographic Information Systems, *Cartography and Geographic Information Systems*, 17:7–15.

Mumford, E., 1981. Participative Systems Design: Structure and Method, *Systems, Objectives, Solutions*, 1:5–19.

NCGIA, 1990. *NCGIA Core Curriculum—Vol. 3: Application Issues in GIS* (M. Goodchild and K. Kemp, editors), National Center for Geographic Information and Analysis, University of California, Santa Barbara.

Norman, D.A., 1988. *The Design of Everyday Things*, Doubleday, New York.

Nunes Alonso, J., 1992. *Los sistemas de información geográfica como herramienta de desarrollo teórico: La construcción de modelos de datos conceptuales*, unpublished doctoral dissertation, Universitat Autónoma de Barcelona, Departament de Geografia, 352 p.

Nyerges, T.L., 1993. Understanding the Scope of GIS: Its Relationship to Environmental Modeling, *Environmental Modeling with GIS* (M. Goodchild, B. Parks, and L. Steyaert, editors), Oxford University Press, New York, pp. 75–93.

Packer, M.J., 1985. Hermeneutic Inquiry in the Study of Human Conduct, *American Psychologist*, 40:1081–1093.

Peuquet, D.J., and T. Bacastow, 1991. Organizational Issues in the Development of Geographical Information Systems: A Case Study of U.S. Army Topographic Information Automation, *International Journal of Geographical Information Systems*, 5:303–319.

Pickles, J., 1985. *Phenomenology, Science and Geography*, Cambridge University Press, Cambridge.

———, 1993. Discourse on Method and the History of Discipline: Reflections on Dobson's 1983 Automated Geography, *The Professional Geographer*, 45:451–455.

Robinson, A., and B. Pechenik, 1976. *The Nature of Maps: Essays Towards Understanding Maps and Mapping*, University of Chicago Press, Chicago.

Sheppard, E., 1993. Automated Geography: What Kind of Geography for What Kind of Society? *The Professional Geographer*, 45:457–460.

Simon, H.A., 1976. *Administrative Behavior, 3rd Ed.*, Free Press, New York.

Smith, D.A., and R.F. Tomlinson, 1992. Assessing Costs and Benefits of Geographical Information Systems: Methodological and Implementation Issues, *International Journal of Geographical Information Systems*, 6:247–256.

Turk, A.G., 1990. Towards an Understanding of Human-Computer Interaction Aspects of Geographic Information Systems, *Cartography*, 19:31–60.

Waters, N., 1993. GIS: Paradigms Lost, *GIS World*, 6(8): 64.

Whiteside, J., and D. Wixon, 1987. Discussion: Improving Human-Computer Interaction—A Quest for Cognitive Science, *Interfacing Thought: Cognitive Aspects of Human-Computer Interaction* (J.M. Carroll, editor), Press, Cambridge, pp. 353–365.

Winograd, T., and F. Flores, 1986. *Understanding Computers and Cognition: A New Foundation for Design*, Addison Wesley, Reading.

Yourdon, E., 1989. *Modern Structured Analysis*, Yourdon Press, Englewood Cliffs, New Jersey.