What does "GIS" mean?

Nicholas R. Chrisman
Associate Professor
Department of Geography Box 353550
University of Washington
Seattle, Washington 98195 USA

chrisman@u.washington.edu
tel: +1 206 543 5870; FAX: +1 206 543 3313

ABSTRACT

Many definitions of "GIS" have been proposed, but they are rarely defended in the peer-reviewed literature. Most definitions in active use have serious limitations. Recent literature includes a variety of proposals to redefine GIS by changing the third word. This paper proposes an extended definition accompanied by a condensed form that contains the key concepts:

"Geographic Information System (GIS) – Organized activity by which people measure and represent geographic phenomena then transform these representations into other forms while interacting with social structures."

Purpose

Writing a definition is at once trivial and deep. To some extent, each writer can simply attach meaning to a particular term as needed for a limited purpose. Lewis Carroll, with his training as a mathematician, had Humpty Dumpty say "When *I* use a word, it means what I choose it to mean – neither more nor less" (Carroll 1872/1987, p. 106). Such an absurdist extreme has become commonplace in the artificial languages used to program computers. However, in more constructive circumstances, definitions can attempt to encapsulate whole bodies of knowledge and to build a common ground of shared understanding. To succeed in such a role, definitions must be written as self-contained units, because they will be quoted and reused without the prior paragraph of explanations. They become, in fact, an element of technology in a broad sense. Though a definition may seem a minor issue, it can become a routine part of instruction and outreach. It can make a difference in communicating among disciplines, professions, and citizen groups.

The GIS literature is replete with definitions of the term "GIS", but at the same time, there is remarkably little reflection about these definitions. This article will review a sampling of definitions of the term and the literature that discusses them. In place of some of the earlier criteria for definitions, this paper offers some grammatical and content goals. It presents a longer and a shorter definition that attempt to live up to the standards, and defends the proposed phrasing. Before performing these tasks, a theoretical basis for this enterprise will be developed by examining how definitions work and how they are adopted.

How definitions work

There are many approaches to words and language that extend far beyond the modest intentions of this paper. However, it is important to note that dictionaries can be written using a whole spectrum of approaches along at least one dominant axis. At one end, there is a normative belief that a word should have a

stable meaning. For example, the French language is officially entrusted to the *Acadé mie Franç aise,* whose "immortals" sit in deliberate judgement over definitions of words wearing archaic hats. Science has also established such deliberative bodies for certain roles. For example, the process of naming a new species of plant or animal involves a highly ritualized international scientific establishment. Such a formalized method attempts to purify the distinction between signifier and signified. The language attempts to model some abstract world of Platonic forms that can be held separate from the specifics of expression and usage. Such dualism has deep philosophical roots, but is often difficult to operate in practice.

At the other extreme, other dictionaries adopt a *laissez-faire* approach, attempting to reflect the shifting shades of meaning that evolve through usage. Dictionaries of the English language have tended to follow Ben Johnson's essentially ethnographic method, using "historical principles" to chronicle the evolution of meaning. This process expects a form of collective unconscious to develop new meanings, not overt and official acts. In this view, a word is not independent of its context; the dualistic model must be abandoned.

Despite the rhetoric of the eminent committee or the invisible hand of the collective, definitions (particularly those of a discipline) are far from neutral. Since they set boundaries, they can be used to claim territory by being inclusive, or to exclude some elements. In the interdisciplinary circumstances of "GIS", a definition must be analyzed as political statement. It must be read as much for what it does not say and what it does not contain as for what it actively asserts. Definition-writing is not some meta-activity conducted outside of the rest of discourse. Unlike coordinate measurements that can be tested against the world (at least within some conventional limits), words connect to reality through a complex cultural pathway. Language is used to reshape the world, to make others see the world from one's perspective. This article adopts its theoretical framework from the literature on the social construction of scientific knowledge

(Barnes 1974; Bloor 1976; Latour and Woolgar 1986; Latour 1993). Specifically, a definition of a specialization like GIS serves as a major "boundary object" – an entity about which various groups agree to disagree (Harvey 1997a; Harvey and Chrisman 1998). Definitions of a term like GIS do matter because they play a role in negotiating agreements between the diverse actors required to make a GIS operate.

In such a complex arena, it may seem futile to attempt to write a new definition. The formalists and the historicists seem to have left little room for individual initiative. Yet, one of the most insidious elements that unifies these extremes is a belief in a form of legal *stare decis* (the principle that a matter once decided should not be revisited). Tired old definitions, like some form of resilient genetic material, can propagate themselves, moving from one author's work to another. When they are accepted without thought, they are perhaps at their most dangerous. I believe that the current state of the definition of "GIS" is in such a situation. The term is taken for granted, understood without being explicitly put into words. Thus, the definition reflects an earlier world, one where "GIS" was a dream, not a gigantic industry, a fact-on-the-ground. I believe that a reformulated definition can help the community realize its ability reshape these seemingly uncontrollable forces through everyday practices.

State of the Definition

The term "GIS" has come to symbolize a technology, an industry, a way of doing work. To some it has come to promise a new world of disciplinary and professional renewal, flowing from the economic expansion of information technology. As buzzword, "GIS" can be as shallow as any computer acronym. Yet, the buzzword is so powerful that it has become a word (pronounced "jees") in professional circles in France, that bastion of linguistic purity. One purpose of producing a definition is to tie the buzzword to some solid foundation.

"GIS" has a few variant origins or interpretations. Among many British

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authors, the term is spelled out as "Geographical Information Systems"; Burrough (1986, p. 6) even places the Latin *sic* next to "Geographic Information Systems". The later spelling has clearer historical precedent; it was after all the Canada Geographic Information System (Tomlinson 1966; 1967) that first used the term. This paper will use the North American variant, in consonance with the editorial policy (Wilson et al. 1996) of this British-based journal.

While definitions pop up everywhere, there is remarkably little attention given to comparing definitions and to evaluating them. Cowen (1988) provided some review of the principles of definitions, giving four approaches to a definition: process-oriented, application, toolbox, and database. Maguire (Maguire 1991) provided a more complete review of selected definitions and described the approach to GIS from three viewpoints: the map view, the database view, and the spatial analysis view. This article will merge these taxonomies to provide a sampling of each kind of definition extant. Although divisions of definitions occur in the literature, in practice it is rather arbitrary to assign a particular definition to just one approach. Some of the definitions reported come from the traditional literature sources, but some are drawn from the world-wide web, a forum of increasing importance for the description of the field and its promotion to newcomers.

Systems flow approach

From the very start, GIS practice emphasized the S word: systems – perhaps the most pervasive metaphor for the twentieth century (Harvey 1997b). Operations research, developed as a distinct practice during World War II, provided a technique of "systems analysis" that helped bring the computer into nearly every part of modern life. GIS was not alone in being conceived as a series of procedures that lead from input to output; from data sources through processing to displays. The most prevalent form of a GIS definition follows this sequence, for example the one adopted by the Chorley report for the UK:

> GIS – a system for capturing, storing, checking, manipulating, analysing and displaying data which are spatially referenced to the Earth.

(Department of the Environment 1987, p. 132)

This definition, with the somewhat novel addition of "checking", bears a direct relationship to the earlier work of the IGU Commission (Calkins and Tomlinson 1977). This has been termed the process approach by Cowen, but the process seems restricted to a work-flow concept with an emphasis on systems terminology. Variants of this text reappear without citation in textbooks, policy documents, and user manuals. Marble (1984, p. 20) elaborated this flow-based definition in more expansive form by detailing four "subsystems":

1. A data input subsystem which collects and/or processes spatial data derived from existing maps, remote sensors, etc.
2. A data storage and retrieval subsystem which organizes the spatial data in a form which permits it to be quickly retrieved by the user for subsequent analysis, as well as permitting rapid and accurate updates and corrections to be made to the spatial database.
3. A data manipulation and analysis subsystem which performs a variety of tasks such as changing the form of the data through user-defined aggregation rules or producing estimates of parameters and constraints for various space-time optimization or simulation models.
4. A data reporting subsystem which is capable of displaying all or part of the original database as well as manipulated data and the output from spatial models in tabular or map form. The creation of these map displays involves what is called digital or computer cartography. This is an area which represents a considerable conceptual expansion of traditional cartographic approaches as well as a substantial change in the tools utilized in creating the cartographic displays.

This definition offers a sense of the stages of operation, but little about the internals. The adjectives "quickly", "rapid" and "accurate" tell us little about the means of organization. The definition of one system as a set of four "subsystems", arranged in linear sequence, adopts a recursive strategy in which systems are explained by more systems.

While the basic system flow definition continues to be used, as the widespread adoption of GIS began in the 1980s, there was a sense that the definition was overly technical (Rhind 1996). One of the most commonly cited alternatives was developed by a Delphi panel of thirty specialists, including the

author of this paper:

> 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. (Dueker and Kjerne 1989, p. 7-8)

This definition encompasses all of Marble's subsystems, with a massive expansion of the actors involved. No longer is this just the software and hardware, this view of GIS includes various social elements. Notice also that the definition carefully distinguishes between the data in the system and the information that results from the system. Each of these improvements reflects the consensus of the Delphi participants, reflecting the experience of implementation. While the Delphi process does help ensure agreement, it also has all the disadvantages of writing by committee. The resulting definition is still firmly in the tradition of the system flow approach.

Systems flow definitions spend little time excluding others; they concentrate on a positive message of internal functions and a systems metaphor.

Content: maps and databases

In contrast to the system flow approach, a content approach defines the GIS by what it contains, either as a special case of more general information systems or as an amalgamation of more specific uses. Geographers often define a GIS with focus on the particular nature of spatial data.

> An information system that is designed to work with data referenced by spatial or geographic coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data, as well as a set of operations for working with the data. (Star and Estes 1990, p.2-3)

The US Geological Survey, in their web pages, takes a similar approach:

> In the strictest sense, a GIS is a computer system capable of assembling, storing, manipulating, and displaying geographically referenced information, i.e. data identified according to their locations. Practitioners also regard the total GIS as including operating personnel and the data that go into the system. (U.S. Geological Survey 1997)

In some related disciplines, such a forestry, the special content is called "maps":

> A form of MIS [Management Information System] that allows map display of the general information. (Devine and Field 1986, p. 18)

The content approach amplifies the reference to geographic content visible in the systems flow definitions, but elevates content to become almost an exclusionary filter. In addition, a definition that relies solely on database content gives very little guidance to what a GIS does.

Another content approach is to list potential uses of a GIS, to work by inclusion, not exclusion. Any attempt to list all the potential uses of a GIS is clearly doomed to failure. When a list is offered, it is usually presented with wonder at the diversity of disciplines involved. Maguire strikes this tone: "The link between these apparently disparate intellectual areas is that they share common technology and methods" (Maguire 1991, p. 11). Indeed, the network of technical linkages in modern society links virtually every component with every other one. The black boxes in a laboratory contain any number of distinct disciplines, distilled into a reliable and indisputable fact, then promptly ignored (Latour 1987). The attempt to place GIS at the center of the universe (or at least as the intersection of four Venn-diagram rings [Computer cartography, Remote sensing, Computer-aided design, and Database management] in Maguire's Figure 1.1) is not very convincing. Maguire's list of fifteen information systems (Table 1) is a hodge-podge of overlapping disciplines and vague assemblages like "Spatial information systems", not a term in any regular use. This list attempts to include diverse application efforts into GIS, the caption states:

> "Example types of GIS classified according to the application area addressed. It is also possible to consider these as alternative names for GIS. (Maguire 1991, p. 12)

> Table 1: List of GIS application areas from Maguire (1991, p. 12)

> Cadastral information system

> Image based information system

> Land data system

> Land information system

> Geographically referenced information system

> Natural resource management information system

Market analysis information system

Multipurpose cadastre

Planning information system

Property information system

Soil information system

Spatial information system

Spatial decision support system

Urban information system

Whether attempting to exclude others or to include a multitude, a definition based on content of GIS is a risky endeavor.

Toolkit approach

In search of the distinctive characteristic of a GIS, Cowen (1988) singled out polygon overlay, and integration of different sources more generally, as the key element that distinguished a GIS software package from competing software systems. Although Cowen eventually crafted a definition based on decision support systems, the article spent most of its time defending the boundaries and erecting barriers to entry. He was not alone at that time in wanting to distinguish the drafting approach of CAD technology from the analytical approach of GIS. For one example, the Technology Exchange Working Group of the early federal coordinating committee prepared a checklist of GIS functions that went on for eight pages (Guptill 1988, p. 30-38).

The ESRI web pages also address the special nature of the software toolkit, an entirely predictable approach from a major software vendor:

A geographic information system (GIS) is a computer-based tool for mapping and analyzing things that exist and events that happen on Earth. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps. These abilities distinguish GIS from other information systems and make it valuable to a wide range of public and private enterprises for explaining events, predicting outcomes, and planning strategies. (ESRI 1997)

Curiously, the special nature of GIS tools seems to draw more from the map display (as in the previous section) than in the "analytical" tools found critical in other versions. Rhind (1996, p. 3), as a preamble to an article on policy issues adopts a "catholic" (meaning universal) definition based on the simplest merger of content and toolkit approaches:

> any system capable of coping with georeferenced data and permitting some form of geospatial selection or query.

His reasoning is that the lines between GIS and other forms of information technology are no longer as strict as they were to Cowen in 1988. In his attempt to be universal, Rhind offers a definition that is so loose that a Rolodex is indistinguishable from a full-function GIS workstation.

The approach to list the toolkit of a GIS is difficult because there are many different kinds of tools. It is hard to select which ones are necessary and sufficient, or even distinctive. The idea of polygon overlay as the indicator might have been relevant ten years ago, but no single tool can serve as indicator for current GIS.

Changing the subject

More recently, there has been a substantial effort to shift the emphasis by declaring that GIS should stand for "Geographic Information Science" (Goodchild 1992). Goodchild's original intent was neatly summarized in his unapologetic chapter in *Ground Truth*:

> GIS ... has done much to remove the traditional isolation between photogrammetry, remote sensing, geodesy, cartography, surveying, and geography (one could add to this list computer science, operations research, spatial statistics, cognitive science, behavioral psychology, and any other discipline with interests in the generic issues of spatial data). In an earlier paper, I argued that these were the disciplines of geographic information *science*, and that it made more sense for the research community to decode the GIS acronym in this way, focusing on the generic issues of spatial data, rather than on the limited solutions offered by today's geographic information *system* products. (Goodchild 1995, p. 42 emphasis in original)

This is a maneuver in the politics of disciplines, a maneuver that has worked.

Journals have been renamed, organizations have taken up the GI Science label. Yet, this proto-discipline did not arise solely from its academic virtues or even from the charisma of its original proponent. This "science" is an attempt to reorient the energy created by the messy confluence of tool, practice, and competing disciplines. GI Science depends upon blurring the meaning of the acronym, and thus the linkage to the expanding world of practical application. In a simpler age, the academic research community played a central role in creating and proselytizing GIS. By claiming that the high-minded side of GIS is GI Science, it gives a space for the research community to control on its own. But all of this is a way of changing the subject. The bulk of the GIS community uses the tools, instead of building them. Declaring a GI Science still requires the research community to consider what it is that the users are doing. There is no escape from the need to define GI Systems

In one recent paper, Wright, Goodchild and Proctor (1997) attempt to draw grand conclusions about GIS as tool or as Science from a few days postings on GIS-L. Pickles' (1997) reply also misses the point that tool and science are not divided by a simple semiotic gesture. The line between tool and science is not simple. Science is constructed by a series of long-term processes that turn speculative and unproven work into firmly established facts that eventually disappear inside black boxes (Latour 1987). Each scientific instrument, such as the hand-held GPS, the wetland coding standard, or the polygon overlay algorithm, was once a subject of research without a preordained answer. Any use of these research-stage proto-tools would have to be specific about the version used and the circumstances of use. When sufficiently accepted, the research project becomes packaged into a larger and larger system that needs no further introduction.

No matter how carefully packaged, no tool is perfectly neutral. Each GIS implementation selects from the toolkit available and fits it to the circumstance with substantial tailoring. Tools emerge from a social and historical context to

respond to changing needs, but tools also alter their users and their surroundings. The set of black boxes available around a laboratory record the intellectual history of the whole culture, putting physics, chemistry, and mathematics together to serve goals never imagined when originally conceived. Latour, (1986) describes the equipment in a microbiology lab at the Salk Institute as mute emissaries from past research projects in other disciplines.

The GI Science proposal is not the only attempt to change the subject. Forer and Unwin (1998) have recently proposed "Geographic Information Studies" as a means to treat "the considerable social, legal and ethical issues". Their article deals largely with the educational community, where studies might seem much more attractive. But, as the definition efforts of Dueker and Kjerne demonstrate, there is no inhibition to broadening the view of systems to include all the components of social, cultural, economic and ethical issues (Chrisman 1987, for another example). To some extent, the creation of separate spheres for users, scientists, and "studiers" diminishes the opportunity to place the social issues in the central focus. Dispute over the term "GIS" signals that there is some inherent value in the acronym, no matter how it is spelled out.

Some criteria for definitions

The current definitions of GIS deserve reexamination. A few requirements of effective writing could help set a higher standard. Dictionary entries can be sentence fragments, but complex relationships may require sentence form. The passive voice hides the agent of an action. For clarity, a definition should use clear subjects, active verbs and specific objects.

In addition to more effective writing, the content of a definition should avoid the exclusionary approach. A positively phrased definition can set an exacting standard, without becoming as quickly dated. The pace of change is often used as a reason to generate new definitions (Rhind 1996, for example), but careful attention to the principle of Tobler's (1976) half-life concepts can produce

definitions that survive through changes in the technology.

A modest proposal

For years, I resisted definitions of GIS. The committee process of Dueker and Kjerne was not particularly satisfying and the epic committee meeting of the National Committee for Digital Cartographic Data Standards made all hopes of collective action seem totally impossible. When I sat down to write a textbook, I skirted around writing a definition. I had adopted a sequence for the book that originated as my reply to the penetrating question one brave student asked me in the sixth week "What is this course all about?" I had replied that the course was all about measurement, and then it was all about representation, then it dealt with transformations, but it was always all about why people wanted you to do the analysis in the first place; a series of issues that I arranged in rings on the blackboard. The current, somewhat simplified, version of these rings appears in Figure 1. As I prepared to send the final manuscript back, I translated these rings into a definition. I sent out a draft to some colleagues and their assistance helped craft this modest proposal:

> "Geographic Information System (GIS) – The organized activity by which people
> - *measure* aspects of geographic phenomena and processes;
> - *represent* these measurements, usually in the form of a computer database, to emphasize spatial themes, entities, and relationships;
> - *operate* upon these representations to produce more measurements and to discover new relationships by integrating disparate sources; and
> - *transform* these representations to conform to other frameworks of entities and relationships.
>
> These activities reflect the larger context (institutions and cultures) in which these people carry out their work. In turn, the GIS may influence these structures." (Chrisman 1997, p. 5)

Of course, a text of 84 words can say more than the typical length of a definition, but my proposed definition is still less than half the length of Marble's subsystems text. This length permits some deliberate inclusion of terms that signal extensions to temporal data (processes as well as phenomena), to

relationships as well as themes and entities. I believe that it places the GIS in the rigorous mode that the GI Science approach wishes to promote. It also gives substantial role to the social component sought by the GI Studies proposal.

This proposed definition can be visualized as a series of nested *rings* (see Figure 1). Unlike the black boxes of the subsystem flow approach, the rings imply connection and interaction. The four inner rings were designed to present the GIS operations by expanding the transformational approach to cartography originally conceived by Tobler (1979).

> At the innermost ring, the process of geographic *measurement* requires choices that can be organized as measurement frameworks. Differences in these measurement frameworks best explain the technical choices of *representation* for geographic information; measurement and representation, in turn, strongly influence the *operations* which can be performed with the information. Finally, *transformations* can convert from one measurement framework to another. Thus, each ring builds upon decisions made at the simpler levels. (Chrisman 1997, p. 1)

These technical components do not operate in a vacuum. The measurements, representations and transformations all serve the goals of institutions, and these, in turn, serve larger social goals. But the information system is not simply a passive player, responding dutifully to social demands. The availability of information shapes social expectations and the cultural expectations of professions and disciplines shape the choices of measurement and representation. The new technology triggers new demands as much as it fulfills unmet demands. So, the social and institutional context of the outer rings provides goals for the system, and it provides the cultural meaning of the worldviews that motivate measurement and representation. In the long run, the rings define a circular process of interdependency, not a linear throughput.

If pressed, I would collapse this definition to the length normally allotted (one word shorter than Dueker and Kjerne):

> Geographic Information System (GIS) – Organized activity by which people measure and represent geographic phenomena then transform these representations into other forms while interacting with social
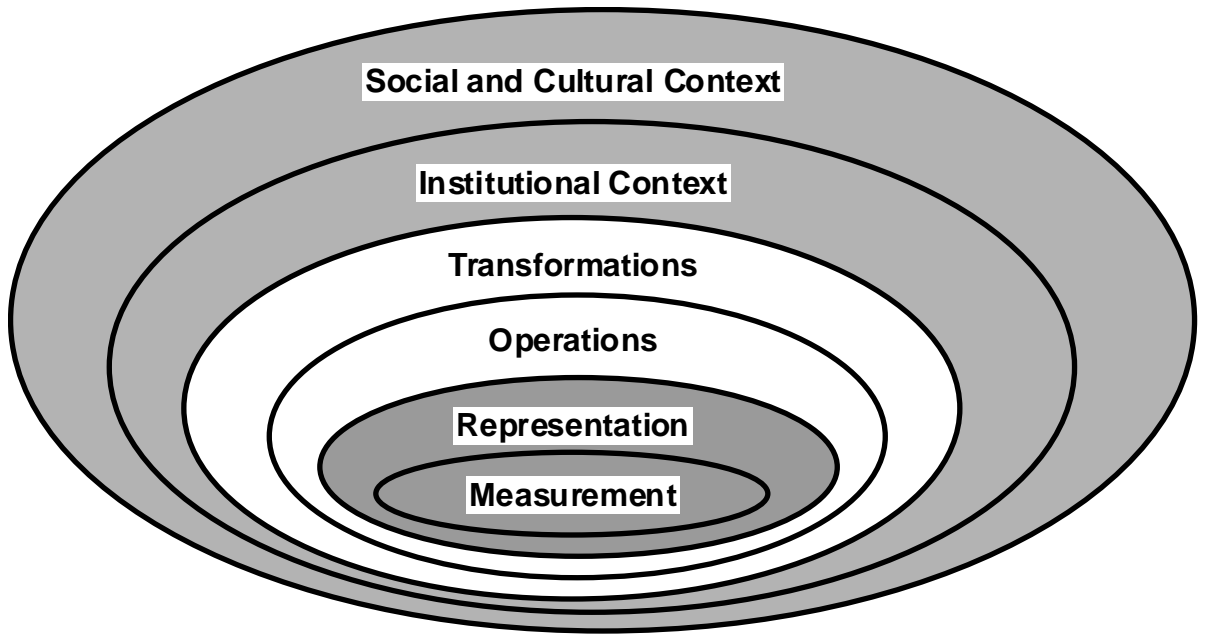
structures.

Conclusion

Eventually, any definition will be judged by the community. If this article inspires some critical attention to the definitions we use, it may score a modest success. If the proposed definition replaces the "systems flow" definitions that pervade the discipline, and is so commonly accepted that it no longer needs a citation to this article, the success will be too strong. The community needs to recognize the power of words to shape the environment. No definition should become so accepted that we do not question it.

Acknowledgements

Illustration caption

Figure 1: Nested rings that embed the decisions involved in operating a geographic information system. Each ring encapsulates all the more technical decisions inside, mobilizing them in a more complex structure. See text for full description. Simplified from Figure P-1 (Chrisman 1997, p. vii).

Social and Cultural Context

Institutional Context

Transformations

Operations

Representation

Measurement

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