Topic Page: Geographic information systems

Definition: **geographic information system (GIS)** from *Dictionary of Energy Measurement*. the computer hardware, software, and technical expertise applied to assemble and analyze geographical data, especially the correlation of databases with graphic displays to present information; frequently employed in environmental studies.

Image from: **A Dot Density Map of the Distribution of...** in *Encyclopedia of Health Services Research*

Summary Article: **Geographic Information Systems (GIS)**
From *Encyclopedia of Geographic Information Science*

Geographic information systems (GIS) are fundamentally concerned with building shared understandings of the world in ways that are robust, transparent, and, above all, usable in a range of real-world settings. As such, GIS is an applied-problem-solving technology that allows us to create and share generalized representations of the world. Through real-world applications at geographic scales of measurement (i.e., from the architectural to the global), GIS can provide spatial representations that tell us the defining characteristics of large spaces and large numbers of individuals and are usable to a wide range of end users. They allow us to address significant problems of society and the environment using explicitly spatial data, information, evidence, and knowledge. They not only tell us about how the world looks but, through assembly of diverse sources of information, can also lead us toward a generalized and explicitly geographical understanding of how it works. As such, GIS provide an environment in which the core organizing principles of geographic information science can be applied to current real-world issues and are core to the development of spatial analysis skills.

The spatial dimension is viewed as integral to problem solving in most management and research settings. In the world of business and commerce, for example, recent estimates suggest that global annual sales of GIS facilities and services may exceed $9 billion and are growing at a rate of 10% per annum. The applications of GIS and their associated spatial data to which these figures relate range from local and national government departments; to banking, insurance, telecommunications, and utility and retail industries; to charities and voluntary organizations. In short, an enormous swath of human activity is now touched, in some form or other, by this explicitly geographical technology and is increasingly reliant on it.

Defining GIS

There are many definitions of GIS, most of which are in relation to a number of component elements. The term *geographic information systems* incorporates all of the following:

A software product, acquired to perform a set of well-defined functions (GIS software)

Digital representations of aspects of the world (GIS data)

A community of people who use these tools for various purposes (the GIS community)

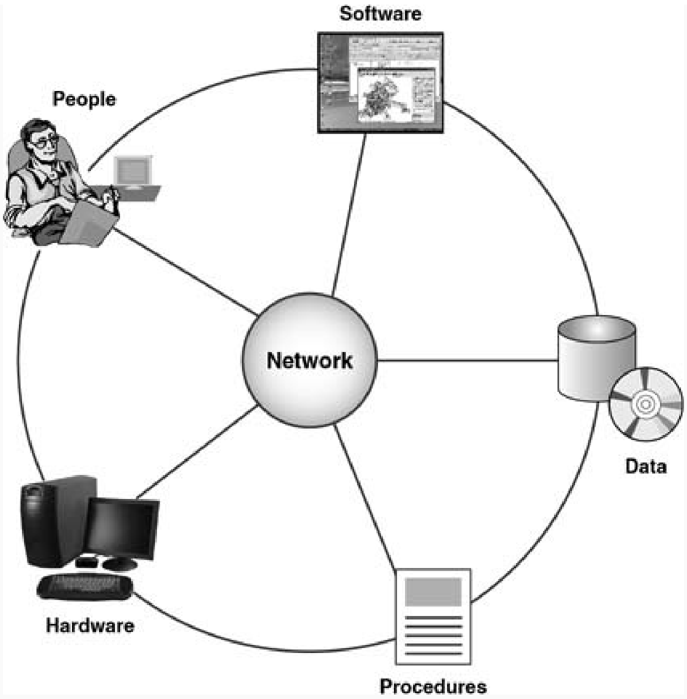
The activity of using GIS to solve problems or advance science (geographic information science).

GIS today is very much a background technology, and most citizens in developed countries interact with it, often unwittingly, throughout their daily lives. As members of the general public, we use GIS every time we open a map browser on the Internet, use real-time road and rail travel information systems for journey planning, or shop for regular or occasional purchases at outlets located by the decisions of store location planners. GIS has developed as a recognized area of activity because although the range of geographical applications is diverse, they nevertheless share a common core of organizing principles and concepts. These include distance measurement, overlay analysis, buffering, optimal routing, and neighborhood analysis. These are straightforward spatial query operations, to which may be added the wide range of transformations, manipulations, and techniques that form the bedrock of spatial analysis.

The first GIS was the Canada Geographic Information System, designed by Roger Tomlinson in the mid-1960s as a computerized natural resource inventory system. Almost at the same time, the U.S. Bureau of the Census developed the DIME (Dual Independent Map Encoding) system to provide digital records of all U.S. streets and support automatic referencing and aggregation of census records. It was only a matter of time before early GIS developers recognized the core role of the same basic organizing concepts for these superficially different applications, and GIS came to present a unifying focus for an ever wider range of application areas.

Any detailed review of GIS reveals that it did not develop as an entirely new area, and it is helpful to instead think of GIS as a rapidly developing focus for interdisciplinary applications, built on the different strengths of a number of disciplines in inventory and analysis. Mention should also be made of the activities of cartographers and national mapping agencies, which led to the use of computers to support map editing in the late 1960s, and the subsequent computerization of other mapping functions by the late 1970s. The science of earth observation and remote sensing has also contributed relevant instruments (sensors), platforms on which they are mounted (aircraft, satellite, etc.) and associated data processing techniques. Between the 1950s and the 1980s, these were used to derive information about the earth's physical, chemical, and biological properties (i.e., of its land, atmosphere, and oceans). The military is also a longstanding contributor to the development of GIS, not least through the development of global positioning systems (GPS), and many military applications have subsequently found use in the civilian sector. The modern history of GIS dates from the early 1980s, when the price of sufficiently powerful computers fell below $250,000 and typical software costs fell below $100,000. In this sense, much of the history of GIS has been led by technology.

Today's GIS is a complex of software, hardware, databases, people, and procedures, all linked by computer networks (see Figure 1). GIS brings together different data sets that may be scattered across space in very diverse data holdings, and in assembling them together, it is important that data quality issues are addressed during data integration. An effective network, such as the Internet or the intranet of a large organization, is essential for rapid communication or information sharing. The Internet has emerged as society's medium of information exchange, and a typical GIS application will be used to connect archives, clearinghouses, digital libraries, and data warehouses. New methods for trawling the Internet have been accompanied by the development of software that allows users to work with data in remote Internet locations. GIS hardware fosters user interaction via the WIMP (Windows, icons, menus, pointers) interface and takes the form of laptops, personal data assistants (PDAs), in-vehicle devices, and cellular telephones, as well as conventional desktop computers.



The Components of Geographic Information Systems

In many contemporary applications, the user's device is the *client*, connected through the network to a *server*. Commercial GIS software is created by a number of vendors and is frequently packaged to suit a diverse set of needs, ranging from simple viewing and mapping applications, to software for supporting GIS-oriented Web sites, to fully fledged systems capable of advanced analysis functions. Some software is specifically designed for particular classes of applications, such as utilities or defense applications. Geographical databases frequently constitute an important tradeable commodity and strategic organizational resource, and they come in a range of sizes. Suitably qualified people are fundamental to the design, programming, and maintenance of GIS: They also supply the GIS with appropriate data and are responsible for interpreting outputs.

The Role of GIS

In the broadest sense, *geographic* means "pertaining to the earth's surface or near surface," and, in their most basic forms, GIS allow us to construct an inventory of where things (events, activities, policies, strategies, and plans) happen on the earth's surface, and when. GIS also provide tools to analyze events and occurrences across a range of spatial scales, from the architectural to the global, and over a range of time horizons, from the operational to the strategic. GIS does this by providing an environment for the creation of *digital representations*, which simplify the complexity of the real-world using *data models*.

Fundamental to creation and interpretation of GIS representations is the "first law of geography," often attributed to the geographer Waldo Tobler. This can be succinctly stated as "everything is related to everything else, but near things are more related than distant things." This statement of geographical regularity is key to understanding how events and occurrences are structured over space. It can be formally measured as the property of *spatial autocorrelation* and along with the property of *temporal autocorrelation* ("the past is the key to the present") makes possible a fundamental geographical statement: The geographical context of past events and occurrences can be used to predict future events and occurrences. As human individuals, for example, our current behavior in space often reflects our past spatial behavior.

Prediction implies regularity and the ability to devise a workable understanding of spatial processes. Yet regularities worthy of being described as laws are extremely rare, if not entirely absent from social and environmental science. It is usually the case that the best that we can hope for is to establish robust and defensible foundations upon which to establish generalizations, based upon observed distributions of events and occurrences. The challenges of effective generalization are legion. We may think of much of our own spatial behavior (such as the daily commute to work or shopping trips) as routine, almost perfectly repetitive. Yet when we come to represent the spatial and temporal activity patterns of groups of individuals, the task becomes error prone and far from trivial. This is also true of spatial and temporal representations in general—be it our interest in the representation of travel-to-work behavior, shopping, or disease diffusion, for example. “Good GIS” is in part about recording as many significant spatial and temporal events as possible, without becoming mired in irrelevant detail. The art of GIS is fundamentally about understanding how and why significant events may be unevenly distributed across space and time; the basic science of GIS is concerned with effective generalization between and about these events. Art meets science in various aspects of GIS—for example, in scientific visualization that clarifies rather than obscures the message of geographic data; in “ontologies” that facilitate plausible representation of the real world; and in the choices and conventions that facilitate manipulation and management of geographic data. In short, effective use of GIS requires awareness of all aspects of geographic information, from basic principles and techniques to concepts of management and familiarity with areas of application.

In this way, GIS helps us to manage what we know about the world; to hold it in forms that allow us to organize and store, access and retrieve, and manipulate and synthesize spatial data and to develop models that improve our understanding of underlying processes. Geographic data are raw facts that are neutral and almost context free. It is helpful to think of GIS as a vehicle for adding value to such context-free “bits and bytes” by turning them into information through scientific procedures that are transparent and reproducible. In conceptual terms, this entails selection, organization, preparation for purpose, and integration. Spatial data sources are in practice often very diverse, but GIS provides an integrating environment in which they may be collated to support an *evidence base*. Through human interpretation, evidence is assembled into an individual’s *knowledge base* of experience and expertise. In this way, geographical data can be related to specific problems in ways that are valid, consistent, and reproducible and as such can provide a cornerstone to *evidence-based policy*.

This is the cumulative manner in which GIS brings understanding of general process to bear upon the management and solution of specific (natural and humanmade) problems that occur at unique points on the earth’s surface. As such, GIS brings together the idiographic (the world as an assemblage of unique places, events, and occurrences) and the nomothetic (the quest to identify generalized processes) traditions of understanding—in the context of real-world, practical problem solving. Many such problems involve multiple goals and objectives, which often cannot be expressed in commensurate terms, yet a further strength of GIS is that it allows the formulation and application of explicit conventions for problem solving that are transparent and open to scrutiny. Analysis based around GIS is consistent with changes to scientific and professional practice: specifically, the challenges posed by mining today’s enormous resources of information, the advent of interdisciplinary and interagency team collaborations, the increasing rapidity of scientific discovery, and the accelerating pressures to deliver solutions on time and within budget.

Conclusion

At its core, GIS is concerned with the development and transparent application of the explicitly spatial core organizing principles and techniques of geographic information science, in the context of appropriate management practices. GIS is also a practical problem-solving tool for use by those intent on solving real-world problems. The spatial dimension to problem solving is special because it poses a number of unique, complex, and difficult challenges, which are investigated and researched through geographic information science. Together, these provide a conduit for analysis for those working in a range of academic, industrial, and public service settings alike.

High levels of economic activity and professional interest do not necessarily equate with an increased likelihood of identifying scientific truth, and it is the remit of geographic information science to identify and provide generic safeguards for the fullest possible range of applications. GIS-based representations of how the world works often suggest how capital, human, and physical resources should be managed or how the will of the individual should be subjugated to the public good. This can raise important ethical, philosophical, and political questions, such as questions of access to and ownership of information or the power relations that characterize different interest groups in civil society. Such general concerns about the use of technology should be used to inform issues of ethics and accountability, but they do not call into question their raison d'être.

See also

Critical GIS

Database Design

Database, Spatial

Data Modeling

Distributed GIS

Enterprise GIS

Historical Studies, GIS for

Licenses, Data and Software

Public Participation GIS (PPGIS)

Quality Assurance/Quality Control (QA/QC)

Representation

Software, GIS

Spatialization

System Implementation

Web GIS

Further Readings

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