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Introducing the Identities of GIS

The Success of GIS

GIS is enjoying a boom. It is increasingly recognized by disciplines outside geography, and, to many, epitomizes ''modern geography.'' Software sales exceed seven billion US dollars annually; students flock to GIS classes in colleges and universities; on-board navigation systems are the mark of a luxury car; police officers are routinely trained in GIS; organ donation has been rationalized using GIS; epidemiologists use GIS to identify clusters of infectious disease; archaeologists use it to map sites; and Starbucks® is reputed to use GIS to site its very successful coffee shops. Indeed, the list of GIS uses is extraordinarily comprehensive; the technology pervades many aspects of modern life. Technical advances in GIS have proceeded before our ability to realize and understand its potential effects. Means of integrating the pervasive role and influence of GIS have not kept pace with the development and proliferation of the technology. Indeed, many people do not recognize the acronym; they are even less likely to be able to tell you how GIS has affected their everyday lives. But it has.

This book is designed to inform the reader about precisely how GIS affects them as well as myriad social processes. It introduces what GIS is, how it is understood differently in different contexts, how it works, the importance of data, how data are stored and manipulated, and what contemporary GIS research looks like. It surpasses a mere descriptive account, however, in that it introduces and explores philosophical implications of using GIS whether for research, planning, marketing, environmental management, or other tasks. These are complicated issues, but necessary to understand the full scope of GIS. The book is unique in that it is not a ''how-to'' guide for technically minded students. Rather it aims to introduce the intellectual territory and practice of GIS to a wide variety of people. Indeed, its audience is catholic encompassing interested physical and social geographers, GIS users, students, and anyone who has worked with or wondered about GIS. It is designed to illustrate how GIS affects people by changing the way they do everyday tasks from wayfinding to data collection.

Given the ubiquity of GIS, its value would seem to be undisputed. Except perhaps in the discipline of geography. Academic geographers have a love/hate relationship with GIS perhaps because we are so close to its faults and biases. This relationship is made more complex because GIS represents only one lens on the physical and social world, but this is the face to which the world has had the most exposure to, especially in the last decade. Incoming undergraduate students routinely know of GIS, but are less likely to be familiar with qualitative research techniques used by some human geographers, or about the use of ground-penetrating radar by geomorphologists. The ubiquity of GIS has perhaps colored the perception of geography, and this has a bearing on the identity of all geographers.

It may be surprising then to learn that GIS does not have its own fixed and secure identity. It suffers from the scourge of being many things to many people. To a municipality, GIS is the software that allows planners to identify residential, industrial, and commercial zones. It maps the exact location and survey coordinates of each taxable property, and provides answers to queries such as: ''how many properties would be affected by the addition of an extra lane to Highway 1 between 170 and 194th streets?'' To a university researcher who must define the boundaries of communities that enjoy varying health outcomes, GIS is a different animal. It is not a piece of software, but a scientific approach to the problem: ''how do we define crisp boundaries to demarcate fuzzy and changeable phenomena?'' The latter is a fundamentally philosophical issue that must be resolved through computing. These two types of questions are very different. One is interested in ''where'' spatial entities are or might be while the other is concerned with ''how'' we encode spatial entities (e.g., communities, urban/rural areas, forests, roads, bridges, and anything that might appear on a map), and the repercussions of different methods of analysis on answers to geographical questions. Both are asked, however, with respect to GIS, and they point to the myriad ways that GIS can be defined and perceived – the basis of its identity problem. And identity, as a cursory review of present world politics will confirm, is closely linked to history.

Where Does GIS Come From? A Technical History

The roots of GIS' identity problem date back to the 1960s when the technology and epistemology that underlie it were first being developed. Methods of computerizing cartographic procedures were coincident with the realization that mapping could segue neatly into analysis. In 1962, Ian McHarg, a landscape architect introduced the method of ''overlay'' that was later to become the *sine qua non* methodology of GIS. He was searching for the optimal route for a new highway that would be associated with suburban development. His goal was to route the highway such that its path would involve the least disruption of other ''layers'' of the landscape including forest cover, pastoral valleys, and existing semirural housing. He took multiple pieces of tracing paper, one representing each layer, and laid them over each other on a light table. By visually examining their intersections, he was able to ''see'' the only logical route. The process of overlaying map layers is depicted in Figure 1.1. Ironically,

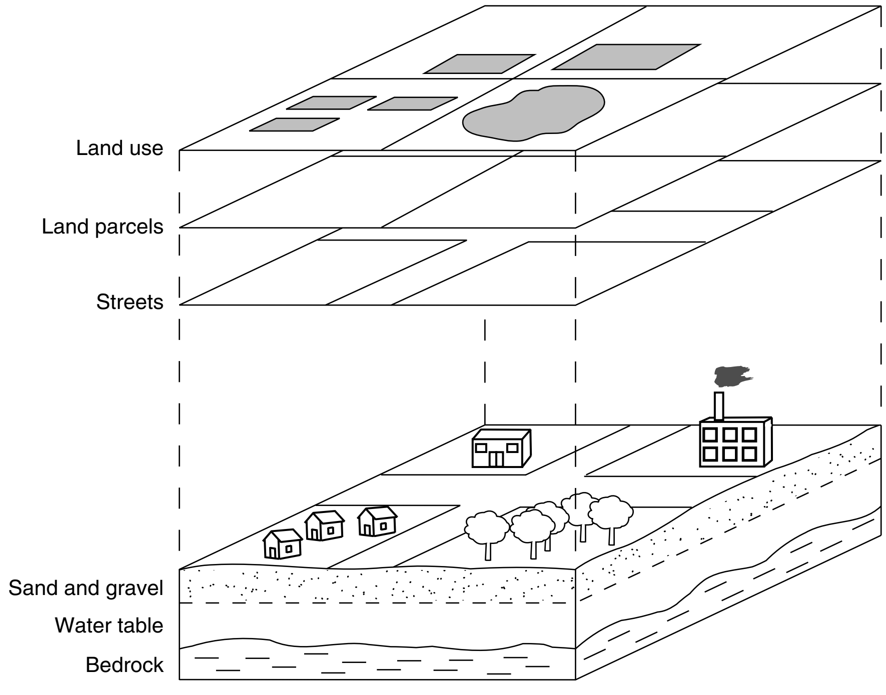


Figure 1.1 *Overlay of multiple layers.*
This process allows policy and decision makers to visualize possibilities and impediments associated with location of strategic facilities.

none of McHarg's initial analysis was done using a computer. Indeed, computers of the day were very primitive, and required massive physical and human resources to run. It is the metaphor of overlay, however, that was integrated into early GIS, and became the basis for a range of analytical techniques broadly known as ''spatial analysis.''

Spatial analysis is differentiated from ''mapping'' because it generates more information or knowledge than can be gleaned from maps or data alone. It is a synergestic means of extracting information from spatial data. Mapping, however, represents geographical data, with varying degrees of fidelity, in a visual form. It does not create more information than was originally provided, but does provide a valuable means for the brain to discern patterns, especially given that more than 50 percent of the brain's neurons are used for visual intelligence. In the early development stages of GIS, however, few people recognized the power of analysis, and the technology was generically referred to as ''computerized cartography.'' As such, GIS made a very poor showing. Early computerized maps were very primitive compared to the exquisite product possible with manual cartography. Figure 1.2 illustrates an early computerized map juxtaposed to a comparable map of the same area. This comparison makes it easy to imagine the basis for initial resistance to GIS from geographers used to enjoying the aesthetic pleasures of maps manually produced by skilled cartographers.

The visual merit of traditional maps acted, however, as a decoy, a distraction from the incipient power of computerized spatial analysis.

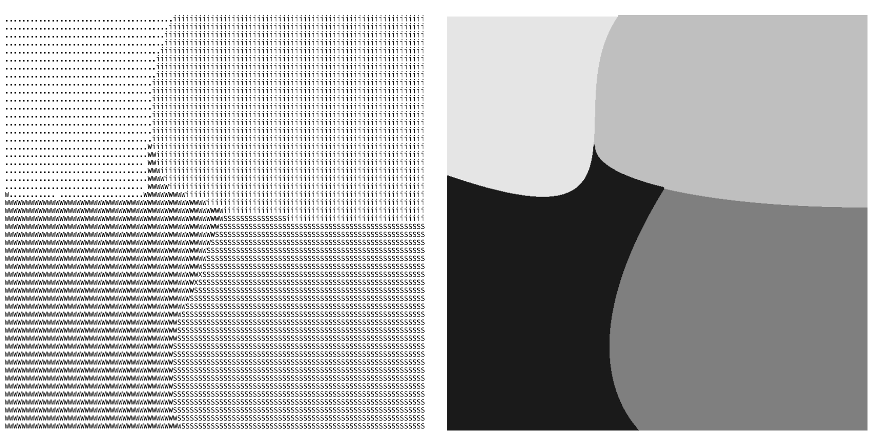


Figure 1.2 *An early computer display of differentiated spatial zones juxtaposed to a comparable map of the same areas using present-day technology. The graphical limitations of early computerized cartography inhibited the adoption of GIS methods for many geographers for whom the cartographic paradigm was paramount.*

That power was first explored in the late 1950s and early 1960s by researchers in the United States. Harold McCarty at the University of Iowa and William Garrison at the University of Washington were both experimenting with computational methods for analysis of large geographical data sets (N. Chrisman, 1988, personal interview). Influenced by the quantitative revolution and the development of computers, researchers began to develop tools that could be used to analyze and display spatial data.

One of the earliest computer cartography systems was developed in Canada, the brain child of Roger Tomlinson and Lee Pratt who met while sitting next to each other on an airplane (Tomlinson, 1988). Tomlinson had been using aerial photography to map forest cover in order to recommend locations for new growth. Lee Pratt worked for the Canadian Ministry of Agriculture. The Ministry wanted to compile land use maps for the entire country, maps that would describe multiple characteristics including agriculture, forestry, wildlife, recreation areas, and census divisions. Tomlinson suggested that they pioneer a computerized system in which land use zones were digitally encoded so that they could be overlaid with other relevant layers such as urban/rural areas, soil type, and geology. This happenstance meeting led, in 1964, to the Canada Geographical Information System (CGIS). The name of the system was bestowed by a member of Parliament – an instance in which sheer contingency cast a long shadow!

This Canadian version of the history of GIS is paralleled by efforts in the UK and United States during the same period. David Rhind (1988), a member of the UK Ordnance Survey has identified two streams of innovation in the development of GIS. The first was initiated by traditional cartographers who (slowly) began to recognize the merits of digitizing spatial information, and creating automated maps in a cost-effective manner. Parallel developments among quantitative geographers were initially quite separate. Brian Berry, Waldo Tobler, and Duane Marble in the US, and Tom Waugh and Ray Boyle in the UK began to develop algorithms and computer code to solve spatial problems. Their work became the basis of spatial analysis in GIS (N. Chrisman, 1988, personal interview.

In the US, the Harvard Graphics Laboratory was a tinderbox of the GIS revolution. Research at the lab established an efficient method for computerized overlay using polygon (vector) boundaries. The lab was populated by a host of researchers who continue to influence the development of GIS today including Nicholas Chrisman and Tom Poiker. A diaspora of researchers from the Harvard Laboratory in the 1970s contributed to the dissemination of GIS especially into the private sector. Scott Morehouse, a junior member left in 1981 to work for a company in

California called Environmental Research Systems Inc. (ESRI). At ESRI, Scott redeveloped the algorithm for vector overlay which became a cornerstone of the program ArcInfo®. This dispersion of ideas from the Harvard Lab was the beginning of one GIS identity: that linked to software packages, hardware systems, and technology in general (Chrisman, 1998).

The Messy Business of Digging For Roots: GIS's Intellectual Antecedents

The development of GIS, however, is not rooted solely in computer laboratories in the mid-twentieth century. It is arguably an outgrowth of attempts to automate calculation in the nineteenth century reflected in efforts, for example, to code population data for the US census in 1890. Pre-eminent GIS scholar, Michael Goodchild (1992), makes the point that GIS was developed during a period when information was increasingly being translated into digital terms and disseminated widely. If geographers hadn't explored the possibilities of digital manipulation of spatial data, other disciplines would have initiated the process. As it is, many roots of GIS are in disciplines other than geography including landscape architecture and surveying. Many GIS scholars regard GIS as an inevitable development, in the light of rapidly converging information technologies in a number of disciplines, combined with a recent history of spatially oriented, quantitative research questions in geography. An increase in scales of counting and analysis is part of a broader social and political movement toward enumeration and control of populations. Like all technologies, GIS is an outcome of both social and technological developments.

All disciplines have intellectual roots, or modes of thinking about phenomena that explain why certain methodologies are used, and certain knowledges privileged. Given that GIS is a relative newcomer to geography, one might think that it would be easy to nail down its intellectual antecedents. But the reverse is true. Although some human geographers claim that GIS is a direct descendant of the quantitative revolution, GIS researchers are loathe to accept this simplistic genealogy. They argue that its antecedents are more complex, comprising a number of threads which were, by circumstances of academic and technical progress, merged into GIS. Others regard GIS as a vehicle for quantitative models but profoundly more than a sum of techniques. Still other researchers argue that GIS transcended the quantitative revolution by incorporating visual intuition. There is a further sense that it is futile to categorize GIS' historical relationships, especially when they arguably began in the nineteenth century with the collection of statistical information about citizenry.

GIS was certainly one vehicle for the introduction of spatial techniques into the discipline but it piggybacked on quantitative methods. These two approaches were merged with the introduction of computer programming to solve spatial problems in the 1970s. Many geographers argue, however, that GIS is more than a vehicle to transport quantitative techniques into geography. According to Nancy Obermeyer, GIS bears the same relationship to the quantitative revolution that a calculator bears to mathematics. ''On one hand, the operations that are clear-cut can be done more simply but . . . you still need to understand the models and the conceptual issues that underlie it'' (cited in Schuurman, 1999a, 24). In other words, GIS draws upon models developed in the quantitative revolution but meaningful implementation still requires an understanding of how those models function in a spatial and algorithmic context. Having a GIS on your desk is not sufficient to implement quantitative models. Users are still required to understand how to frame the questions and wager the degree to which the question is appropriate in the context of the available data.

There is a divide between those who emphasize GIS' links to quantitative analysis, and those who regard it as an extension of mapping. Much early GIS simply involved using the brute force of computer cartography to map data distributions. David Rhind (1988) notes that there was a divide between people using the computer to *analyze* spatial data and those using it to *print* data in graphical form. Waldo Tobler, a legendary figure in both spatial analysis and cartography, used the computer to draw and calculate projections but remained a true cartographer in that he viewed transformation (spatial analysis) as a means to graphic representation, rather than an end in itself (Schuurman, 1999b). The argument is increasingly moot as, since the 1970s, output from analytical operations has been ported to printers for display – the basis of modern GIS.

Despite demonstrated antecedents of GIS in cartography and quantitative methods, there is an inchoate but emphatic sense, among researchers, that GIS extends quantitative techniques. By making them more accessible, many feel that it has imbued them with a more *intuitive* cast. One of the chief virtues of GIS is that it allows the visualization of spatial data as well as providing a means of utilizing fuzzy data. While the quantitative science prefers clear and precise ''facts,'' GIS provides a way to include data that is not so pristine. It presents geographers with ways to visualize spatial arrangements and, in the process, recovers intuition from the wasteheap to which it was relegated during the quantitative revolution. Researchers in ''scientific'' visualization stress that it is the relation of graphical display to communication of information that distinguishes the methodology. The methodology is indeed superceded by the power of the image. This topic is treated with greater detail in Chapter four, and Figure 4.17 illustrates the influence that an image has in conveying information. In this example, the large spike in incidences of tuberculosis delivers information more powerfully than a table showing incidence of illness in various postal codes.

In GIS, visualization is emerging as a subspecialty that focuses on how humans interpret visual imagery, and algorithms for data manipulation and patterns of human-computer interaction. A surface map of elevations conveys a more easily interpreted feel for the landscape than a table that assigns an elevation to each grid cell for the same area. Visualization is used to manufacture meaning from data, through rendering it in image form. GIS incorporates ongoing research into geographic visualization but, more to the point, it is based on the very principles that have recently brought scientific visualization to the fore. Geographers have always used graphical representations to ''see'' spatial patterns.

GIS researchers perceive its visuality as a means of increasing the accessibility and meaning of spatial analysis. In a decision-making context, for instance, visual display often leads to *intuitive* conclusions about cofactors for a given incidence. This reliance on visual intuition constitutes a seemingly ''unscientific'' approach but it is one that finds increasing support in cognitive research which has demonstrated that people are able to discern information from visual display with greater facility than from tables or printed text. Furthermore, many scientists report that people ''reason'' using imagery. Visual images are processed by the viewer differently than numerical or textual output.

Despite recent incorporation of intuition and visualization into GIS' repertoire, it is difficult to dispute that there are ''cultural affinities'' between GIS researchers and quantitative geographers. Strenuous differentiation of GIS from ''simple'' quantitative analysis signals perhaps a reluctance to be tarnished with the same criticisms as have been leveled at mathematical modelers. It also points to a firm conviction, on the part of developers, that GIS surpasses the limitations of conventional analyses through its visuality. Consistent with a tendency to distinguish GIS from other strands of geography is a recent twist on its appellation. GIS now routinely refers to geographic information *science* rather than systems. The name shift points to qualities associated with the technology as well as its disciplinary context.

What Does the Acronym GIS Stand For? The Two Faces of GIS

Definitions of GIS tend to focus on the collection of hardware and software that are associated with the technology. A standard recital of what geographic information *systems* are might mention necessary components such as: methods of data input, analysis, mapping, and output associated with spatial data. Such definitions focus on a collection of practices, hardware, and software that have become known as GIS. Each of these algorithms, bits of metal, and computer code have their own ethnography, but they are so closely linked in the minds of their users as to form a ''black box.'' The term black box was promoted in the popular literature (well, popular for academics) by Bruno Latour (1987) who argued that new scientific knowledge is at first disputed and references to it use copious citations to establish its legitimacy. As the concept – or technology – is better established, it is simply assumed to be true and good, and references and justification are no longer required. The term black box is suitable for one of GIS' identities – the systems identity. Most users, after all, who use a hydrological model embedded in ArcInfo® – a popular GIS program – don't question its legitimacy. Seldom does any one ask how their GIS software decided on the boundaries of the colored polygons that illustrate areas of different income level in a city. Nor is the spatial analysis routine that determines daily delivery routes for a courier company likely to be disputed. GISystems are assumed by the vast majority of users to produce true results.

Close by in a parallel universe, geographic information *science* is concerned with precisely these questions. GIScience is, in the simplest sense, the theory that underlies GISystems. It took several decades, however, for this alternate GIS identity to emerge. By the beginning of the 1990s, a sense prevailed among many academic researchers that GIS had forged new intellectual territory. This intimation was first given substance in a keynote speech given by Michael Goodchild, Professor of Geography at the University of California at Santa Barbara, during the July, 1990, Spatial Data Handling conference in Zurich and again at the EGIS (European GIS) meeting in Brussels in April, 1991 (Goodchild, 1992). In each of these addresses, Goodchild noted that the GIS community is driven by intellectual curiosity about the nature of GIS. He argued that it behooves researchers in GIS to focus on fundamental precepts that underlie the technology rather than the application of existing technology. Furthermore, he argued that there are unique characteristics of geographical data, and problems associated with its analysis, that differentiate GIS from other information systems. These properties include: the need to develop conceptual models of space; the sphericity of spatial data; problems with spatial data capture; spatial data uncertainty and error propagation; as well as algorithms and spatial data display. Given the distinctiveness of geographical data analysis and a growing community of researchers dedicated to solving technical and theoretical problems associated with GIS, Goodchild argued that ''GIS as a field contain[s] a legitimate set of scientific questions'' (cited in Schuurman, 1999b). Questions about the underlying assumptions written into the code that comprises GISystems are the basis of GIScience.

A GIScientist would indeed question the premises of a hydrological model. She might ask who devised the model? How well does it work in a glacial environment as opposed to a wetlands? Or, is the model designed for use with vector (polygon) or raster (gridded) data? Other GIScientists are interested in how boundaries are defined. How do different input parameters or measurement systems lead to different boundary definitions, and how do these vagaries affect the results of GIS analysis? Network analysis routines that optimize delivery or repair routes are also subject to deeper investigation. A GIScientist is likely to try and ascertain whether certain neighborhoods are better served than others, and whether travel times accurately reflect changing weather and traffic conditions. These types of questions strike at the efficiency and legitimacy of current GISystems algorithms, and their resolution will greatly increase the reliability of GIS for the average user. They don't represent, however, the entirety of GIScience.

Every stage of GISystems from spatial data collection and input, to storage, analysis, and, finally, output of maps is based on the translation of spatial phenomena into digital terms. At each step of GIS, data are manipulated for use in a digital environment, and these, often subtle, changes have profound effects on the results of analysis. Each of these transformations involves a subtle shift in the representation of spatial entities, and accounting for these modifications and their implications is an important part of GIScience. Physical and social information about the world, once in digital form, is often manipulated and analyzed *in order to* correspond to the researcher's interpretation of the world. Thus, it is of fundamental importance that GIScientists understand how to monitor and account for the effects that transformations have on data. Finally, GIS researchers must understand how to present analyses such that their visual display is consistent with database results.

The work of GIScientists begins even before data are digitally encoded. Spatial phenomena must be delineated and classified in preparation for input to data tables. Classification systems, however, must be compatible with data tables, and this acts as a constraint to the development of categories. Many spatial phenomena manifest multiple characteristics, but not all of them can be included in a database or the data would be infinite. The manipulation of data depends on the attributes that are recorded, or the objects that are defined. Different community boundaries, for instance, will render different results in an assessment of population health. Visualizing GIS results is likewise vulnerable to the vagaries of the digital environment, and must be consistent with human capacity for perception. At a small scale, for instance, only a limited number of attributes can be displayed or the map becomes overcrowded. At a larger scale, a greater number of attributes can be accommodated. Each of these issues has a bearing on how spatial data are analyzed and interpreted.

In the broadest sense, GIScience is the theoretical basis for GISystems, and its research purview is the representation of spatial data and their relationships – in terms of bits and bytes. Working in a digital environment is akin to speaking another language that uses fundamentally different building blocks. If we think of the English language as being composed of 26 letters that can be combined in various ways to form words, sentences, and ideas, then GIS is based on two letters (well, digits – zeros and ones) that can be combined and manipulated to represent and analyze geographical phenomena and relationships. But the environment and rules associated with manipulating geographical objects are quite different from those we are accustomed to using for text and conventional graphics. GIScientists explore how spatial objects become digital entities, what effect that transformation has on their ontologies, how to represent different epistemologies within GIS, how to model relationships between spatial entities, and how to visualize them so that human beings can interpret the results. This pursuit draws on and extends developments in data modeling, computer science, cognition, scientific visualization, and a myriad fields that have emerged in response to information systems.

GIScience is not limited, however, to process-oriented issues. It is engaged with how people represent their geographical environment, and who has the authority to represent space. Public Participation GIS (PPGIS) studies and engages with nonprofit groups and nongovernmental organizations who use GIS to represent themselves, and advocate for change. Other GIScientists address questions about feminism and GIS, and whether the technology is inherently gendered. Stacey Warren (2003) explains that PPGIS and feminism and GIS allow us to move the focus from analysis and representation in GIS to one that views the technology as a ''collaborative process that involves both people and machinery.'' This emphasis on social interactions between users, affected populations, and technology is evident in the growing number of *Critical GIS* scholars who have merged emancipatory agendas and theory from human geography with GIScience.

Developers and researchers postulate that GIScience transcends mere information *systems* and allows users to ask questions about spatial relations that were previously impossible to pose. Its champions argue that geographic information s*cience* extends spatial analysis by virtue of enhanced processing power that allows data-intensive analyses to extend their geographical breadth. They claim that GIScience is a means of investigating previously obscured spatial relationships and contingencies. There is a tension between GIS scholars who view the technology as an emergent phenomenon, capable of initiating a shift in scientific methodology and other geographers who view it simply as a vehicle for concepts that emerge from geography. It is, of course, both. Moreover, GISystems are the medium for ideas that emerge from GIScience. This text uses the acronym GIS in most instances for simplicity to refer to both systems and science. This conflation of terms reflects both the interrelatedness of two pursuits, as well as the fuzzy boundary between them. In cases where their differentiation is important, the distinction is made.

Data In, Information Out: Common Ground Between GIScience and GISystems

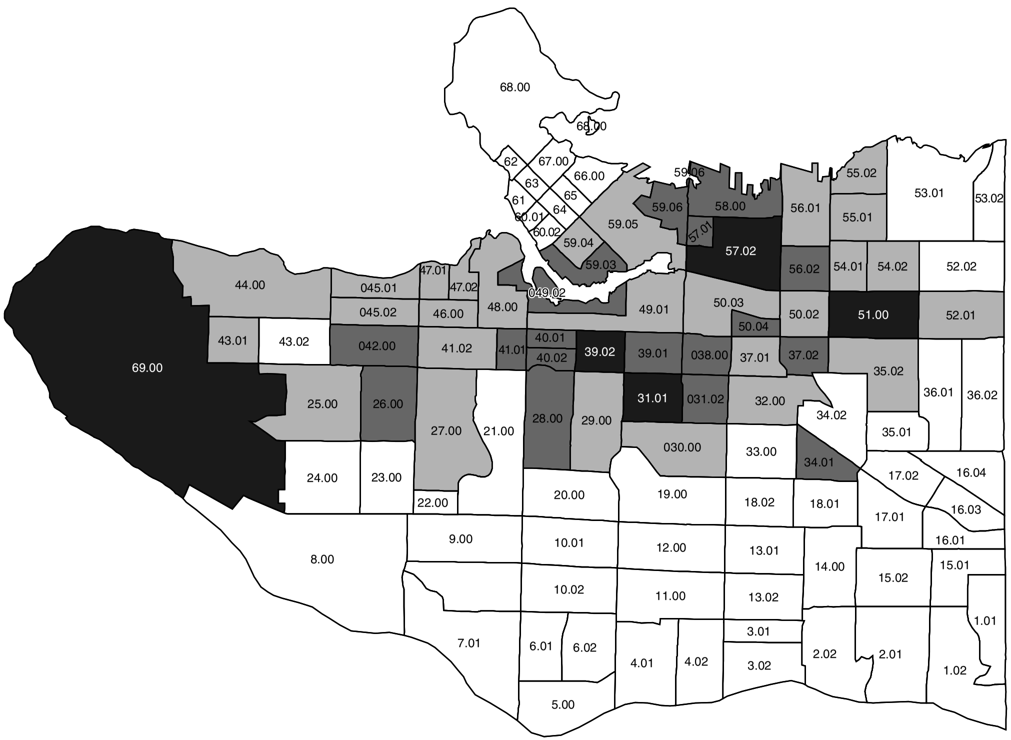
Despite having elaborated on the distinctions between GIScience and systems, the same practices define them. GISystems incorporate processes such as classification, digital encoding, spatial analysis, and output into software, while GIScience provides the theoretical bases and justification for the *way* that these processes are executed. Both start with, and are dependent on spatial data. After the initial problem of identifying which spatial entities (such as houses, communities, forests, roads, or bridges) need to be defined as data, the information must be collected and classified. Classification is a messy business with different categories leading to alternate representations of the same spatial objects (see Chapter 3). People disagree about the definition of the boundaries of spatial objects, and even more strongly about how to put them in categories. You might ask the question, for example, where does the mountain end and the foothills begin? If this can be established, then you are still left with the problem of how to divide the mountains into categories. Is the 1,000 m elevation mark a critical divider, or should all mountains under 5,000 m belong to the same category? These discussions become quite heated when resources are involved. If communities with an income level below a certain mark are eligible for federal funding for health clinics, then the way that income is defined becomes a matter of some importance.

The territory that boundaries encompass has equal bearing. Boundaries drawn around communities yield very different results at different levels of aggregation. Use of Enumeration Areas or EAs (Enumeration Districts in the UK) as the basis for analysis of income levels will yield very different results than using Central Metropolitan Areas comprised of multiple EAs. GIS software is also best suited to crisp, linear boundaries, which creates a predicament for researchers who are not quite certain how to draw the line between, for example, black bear and grizzly bear habitats. Indeed, a fundamental challenge for GIScientists is to find ways to represent the fuzzy boundaries that characterize geographical areas and events using the crisp lines favored in GIS.

Further challenges are associated with modeling spatial phenomena using GIS. Spatial analysis and modeling are increasingly used to predict outcomes, and plan for future development or natural hazards. In the past, GIS was used primarily to manage data, and map distributions. This capacity has been extended by the ability to model interactions among different attributes (characteristics) of the spatial objects, and use this information to predict future events. Land use managers and city planners, for instance, use GIS to study future urban growth based on multiple factors such as density, socioeconomic indicators, geographical constraints (e.g., is the city bounded by mountains or ocean?), road networks, and present land use. Once data are classified, spatial boundaries determined, and analysis complete, the results must be visualized so that users can interpret the information.

Geographic visualization refers both to traditional cartography and to the ability to express knowledge about space and spatial relations in a visual form. The power of GIS emerges partly from its capacity to make visual spatial relationships, and to picture spatial objects in a way that allows users to interpret pattern. Rather than generate tables listing the census tracts associated with children at high risk of contracting Hepatitis A in their preschool, a GIS graphically displays the census tracts, color-coded based on level of risk. The value of visual display in assessing pattern associated with the spread of disease in illustrated in Figure 1.3. At the analysis level, there is no perceptible difference between the statistical results and GIS. The visuality of results, however, allows for intuitive *or* structured exploration of cofactors. The most famous example of visual intuition related to mapping is that of epidemiologist's John Snow's hypothesis that Cholera incidence, during the 1854 outbreak in London, was highest in the vicinity of public wells. Figure 1.4 illustrates the distribution of deaths from Cholera and public water pumps in the Soho area of London in 1854. Based on this map, Dr. Snow reputedly discerned that the use of public wells was linked to Cholera. This conclusion was not straight forward as there were several buildings with high population density in the vicinity of the Broad Street pump in which there were no deaths. Snow relied on his local knowledge to visit the Poland Street workhouse, for instance, and ask from which pump the inhabitants drew water. It turned out that the workhouse had its own well, and none of the 135 inmates had visited the Broad Street pump.

This story demonstrates the value of local knowledge used in conjunction with maps to discern patterns. Visualization in conjunction with GIS



CT	# Children	# Children with hepatitis	%	Risk
23.00	25	1	4%	Low
24.00	17	2	12%	Low
24.00	45	0	0%	Very low
25.00	30	2	7%	Low
26.00	25	6	24%	Medium
31.01	30	11	37%	High
39.01	29	7	24%	Medium
39.02	45	12	27%	High
42.00	19	8	42%	Medium
43.01	18	1	6%	Low
43.02	20	1	5%	Low
43.02	27	0	0%	Very low
44.00	45	1	2%	Low
45.01	35	1	3%	Low
45.02	21	1	5%	Low
47.01	27	2	7%	Low
47.02	16	1	6%	Low
49.01	23	1	4%	Low
50.03	40	1	3%	Low
51.00	25	13	52%	High
52.01	36	1	3%	Low
52.02	24	0	0%	Very low
54.01	38	1	3%	Low
57.01	50	8	16%	Medium
57.02	19	11	58%	High
58.00	26	9	35%	Medium
59.05	38	1	3%	Low
59.06	25	6	24%	Medium
69.00	51	11	22%	High

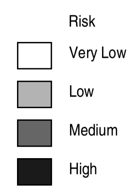


Figure 1.3 *Graphic display of one scenario for incidence of Hepatitis A in daycares in the Vancouver area. Note that areas of high incidence are much easier to discern from the map than the table.*

Figure 1.4 *Cholera outbreaks in London in 1854.*
The stars represent pumps and the dots Cholera cases. By making a map of each incidence, Dr. John Snow was able to make the famous connection between water pumps and the spread of Cholera.

is linked to a trend in science toward using visual displays to understand pattern, and ultimately cause and effect. An example of the power of visuality in science is the discovery/production of the double helix structure of DNA, based on images developed through X-ray crystallography. More recently, the geography of the human genome has been mapped to assist researchers in understanding relationships between chromosomes.

Links between visual intuition, knowledge discovery and computer technology have been the subject of intense research during the past decade. Generating a reliable visual display is, however, much more complicated than it may appear. At the most primitive level, each spatial object must be translated into rows of pixels with varying degrees of color, hue, and saturation. But visualizing spatial data also entails understanding how human beings in different contexts perceive certain symbols, relationships between phenomena, and map representations. Does a picture of a teepee mean camping facilities to everyone in every country? Which colors best represent elevation on a large-scale map? Is the relationship between the bridge and the river more important to map readers than their precise geometry? These are among the questions that geovisualization experts must address as part of the greater project of GIS.

GIS in the World: Who Uses It For What?

GIS has a pervasive reach into everyday life. For users and operators, GIS provides a means to convert data from tables with locational information into maps. Subsequent GIS-generated maps are the basis for spatial decision making in government agencies, businesses, community groups, universities, and hospitals. But the reach of GIS far exceeds people who use the technology. It affects the lives of millions of people in a myriad of ways.

What you eat, where it comes from, and the route it takes to reach your local supermarket are each dependent on GIS technologies. As large-scale agribusiness has proliferated, so too has the role of GIS in food production and agriculture. Business farmers regularly combine remotely sensed imagery and soils analysis to create visualizations of ideal future crop locations and their relationship to local and distant markets. Quotidian farming is often based on ''precision farming techniques'' that allow the farmer to respond to and analyze local conditions in the field with pinpoint accuracy. For instance, a section of a wheat field might have blight. The area circumscribed by the blight is inventoried using global positioning systems (GPS), and then combined with other layers such as soil type, soil chemistry, wheat variety, pesticide load, and irrigation information to determine why that particular section is under duress. Likewise, data about grazing are used to assess the number of beef cattle the land will support based on a given area of pasture. Crop management includes planning to protect vulnerable crops from frost, fires, and over-precipitation or drought. GIS is used to model each of these factors and provide risk factors associated with each depending on the crop and type of farm (e.g., organic or conventional; hand-harvested or machine-picked). Once harvested, crops need to reach a wide range of markets depending on purchase pricing, local preferences, and the cost of transport. Finally, modern farming is sensitive to markets. GIS is used to profile markets, pricing and related transportation costs in order to develop an optimum model for matching crops to consumers.

Municipal management, like farming, has become a high-tech field that is dependent on GIS for delivery of services. A brief inventory of spatial data held by almost every municipality includes property outlines with survey points, tax assessment values, township and country boundaries, roads, waterways, public transportation routes, bicycle paths, aerial photography, park lands, public buildings, and waste collection routes. Each of these spatial entities is associated with a particular GIS functionality. For instance, tax assessment values are linked to individual houses, and are used to evaluate levels of service associated with particular neighborhoods – as well as to keep track of the payment of taxes. Road files, including surface material, embankment, and grade are combined with elevation, weather, and traffic volume and load data to determine which roads are likely subject to accelerated degradation. When roads require repair, closures and reroutings are designed to minimize traffic disruption – though this is seldom clear when you are sitting in stalled traffic. Encouraging bicycle use and green commutes is the goal of an increasing number of urban municipalities. Since 1993, the city of Vancouver, British Columbia, has designated a 135 km bicycle network throughout the city. Since Vancouver has only 5 km of dedicated bicycle path, GIS is used to estimate traffic volumes of both modes of transport during peak commuting periods in order to determine relatively safe bicycle venues. Accessibility of different neighborhoods to parks or public services such as libraries is determined through GIS queries. Waste collection routes are designed using GIS network analysis to reduce exposure of pick-up trucks to traffic, and to optimize the amount of waste gathered on each collection route. This description is an attenuated account of the degree to which GIS has become instrumental in planning our cities.

Urban life is also reliant on GIS in more subtle ways. Pervasive and complex networks provide power, fuel, and water to town and city dwellers. The electrical grids that deliver power are designed and managed using GIS. Each circuit is mapped, and its direction recorded. Circuit can be traced down to the individual customer, and load concentrations can be visualized on a house-by-house basis or for the entire neighborhood. When a circuit needs to be closed down, these data are used to examine all feeding directions in order to switch locations and minimize electrical outages. Specialized software is used with these data to balance transformer loads and minimize loss of power as it seeps through the lines. Recent trends toward privatization of public utilities in Europe and North America have increased pressure to achieve greater efficiencies. GIS has played a role in this trend by offering fully functional systems that not only manage infrastructure, but create virtual models for switching and control systems. These allow managers to test complex scenarios for delivery and load including incorporation of ''cogenerators'' or small businesses that sell spare electrical capacity back to the main grid. The water reservoir and distribution system, natural gas fuel lines, and telephone and cable lines are similarly GIS based and managed.

G-commerce or e-commerce facilitated by GIS has burgeoned as web-based sales proliferate. G-commerce is based on mapping and data analysis tools that allow businesses to construct business-to-business (B2B) and business-to-customer (B2C) portals. A typical B2C portal is illustrated by Amazon.com which sells books, music, and even pharmaceutical drugs directly to consumers in their homes. B2B portals are just as common; they are the basis for ''just-in-time'' delivery systems in which production is wed ever more closely to sales in order to avoid long shelf lives for products – and delayed revenue. G-commerce also provides marketers with the tools to analyze data on customers, sales, and performances using socioeconomic and ''lifestyle'' data. These data are used to visualize consumer trends, and detect opportunities for increased sales. This trend contributes to what Mark Poster (1996) has called the creation of 'digital personae' in which each individual is incompletely described in government and marketing databases based on frequently scanned digital data and derived consumer profiles. These data and accompanying profiles are necessarily incomplete and result in only a rough approximation of each of us. They are the basis, however, for much marketing and determine where new retail outlets are opened, and whether you receive a given flyer in your letter box.

The use of digital data on individuals and communities is not used only by private firms; rather it constitutes the basis for e-governance or electronic governance. E-governance is proliferating as federal and provincial governments begin to use the web to deliver services and allow public access to information. E-governance has an a-spatial, administrative ring to it, but it is powered by GIS and related ''spatially aware'' software. At the municipal level, e-governance entails access to survey lines, property definitions, and tax assessment information. Public notices are web-posted, and forms for everything from dog-licensing to tendering of construction contracts are managed on-line. At the state or provincial level, e-governance is poised to become the vehicle for automobile registration and other services including campground reservation, passport renewal, postal services, and plebiscites. The appeal of e-governance is the promise of more efficient and transparent delivery of services. Its success is dependent, however, on high-levels of web-access which is still not a reality in most countries. Interestingly, India is at the forefront of e-governance technologies and implementation. This speaks to the remarkable intellectual capital the country has as well as the ability of technologies to ''leap-frog.'' The proliferation of cell-phone use in sub-

Saharan Africa by people who never owned a land-line is one example of technology leap-frogging. In the case of India, proponents of e-governance argue that it is a means to eliminate high levels of corruption in the civil service while optimizing the delivery of government services. Detractors counter, however, that e-governance is a means of centralizing power in the hands of a few, and that it lends itself to the indiscriminate collection of digital data about individuals in the absence of privacy restraints. These arguments aside, e-governance is being actively pursued by almost every level of government in many countries. The technology to do so is dependent on spatial data and GIS functionality.

Clearly GIS is interwoven with the fabric of every day life. Understanding the computational and intellectual basis for this technology is an excellent first step toward a better comprehension of the technological bases for modernity. This understanding is a starting point for insights into how the digital realm has come to organize and control so many functions of modern society. The rest of this book sets out to accomplish this task by examining not only GIS the technology but its intellectual and disciplinary ties.

In Chapter 2, the relationship between GIS and human geographers within the discipline of geography is explored as a way of delineating their shared intellectual territory. Explanations for past stormy relations are offered from the perspectives of both disciplinary niches. Many of the initial differences between GIS scholars and social scientists are linked to epistemology or the formal and informal perspectives that inform research methodologies. While epistemology of implementation and development affects GIS, there are myriad contextual factors that influence the technology. The second part of Chapter 2 examines ways in which the development of GISystems and GIScience have been shaped by intellectual traditions, language, and political pursuits.

Using GIS requires data – or information – as well as appropriate software. In fact, data are the primary determinant of relevance for GIS analysis. Students and users of GIS are often captivated by the power of the software, and presume that data are appropriate by virtue of their existence. Chapter 3 is concerned with spatial data including the politics of collection and their relationship to representation, how data are organized, and the challenges of sharing data. The discussion of data ranges from the sociopolitical contexts of collection to the technical challenges of interoperability between data sets. The chapter concludes with an example of data collection and sharing that demonstrates the constraints of the technology, and the politics of implementation.

Data are the servant of analysis in GIS rather than ends in themselves. Chapter 4 delves into the operations that give GIS its power: the constituents of spatial analysis. The early part of the chapter is necessarily devoted to explaining the basis for common spatial analysis operations, their parameters, and the logic upon which they are based. The latter section is devoted to working examples of GIS in environmental management and population health. Finally, the rationalities of GIS analysis are examined with an eye to reinforcing the notion that GIS like statistics strengthens particular actors and agendas.

In the final chapter, the distinction between GISystems and GIScience is revisited in order to afford the reader a more nuanced notion of what everyday work in each of these niches might entail. The potential of GIScience research to enhance the scope of representation afforded by current GISystems is described by providing a brief description of two small, but significant areas of current research: ontologies and feminism and GIS. Both of these areas are of interest to human geographers because they share common literatures and ideals. In the case of ontologies research, the goal is to enable GIS – as a form of representation – to better model the world based on multiple perspectives. Feminism and GIS incorporates and furthers the goals of feminist politics by incorporating and changing GIS to better serve as an ally in these endeavors. The concluding section reiterates the interrelatedness of GISystems and GIScience, and the value of both the discipline and pursuit of geographical knowledge and representation.