CHAPTER 19

What Next? Reflections from the Middle of the Growth Curve

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Introduction

It is now almost exactly 30 years since the heady early days of the Canada Geographic Information System (CGIS) (Chapter by Tomlinson), when the creative energy of a group of Canadian geographers and computer scientists developed the first GIS design and coined the term. Much has happened in the world of GIS since then: much more research has been done; crucial breakthroughs have been made in the key algorithms and data structures; and GIS has emerged as a strong and still-growing application of electronic data processing. The field now has its own journals, magazines, and conferences, its own programs in institutions of higher education, and its own societies. Together, the varied chapters of this book document that history and identify the key events along the way, marked by releases of new software, moves of individuals, decisions of government, and a host of other more or less significant events that together have marked and assisted the emergence of GIS.

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It falls to this final chapter and this author to try to bring the story to some kind of conclusion. Of course, the story is far from concluded—GIS is still growing strongly, perhaps more strongly than at any point in its past. Students of growth patterns might claim that we are still on the upwardly accelerating part of the growth curve and have not yet reached the point of inflection and the decelerating growth which can be expected when it passes 50% of potential. But the skeptical might be more demanding. When all is said and done, what exactly is GIS? Clearly it is very different from the analytic machine for geographic information envisioned by Tomlinson and others in 1966 (Chapter by Tomlinson). No one, however prescient, could have anticipated the impacts of digital technology that have occurred in the interim, particularly in the past five years. The wider world of digital technology that made GIS possible continues on its own growth path and continues to influence both current GIS and our understanding of its future.

Accordingly, the first part of this chapter attempts a summary and synthesis of the current state of GIS. The following two sections first review changes that have occurred in the larger environment of digital computing and then link them to the development of GIS. This leads to a section on prospects for continued growth. Current limitations to growth are reviewed, with a look at the potential dangers facing GIS through misuse and failure to understand the technology's social implications and its setting within broader societal concerns. Finally, the chapter ends with some comments on growth directions and the role current research may play in making them feasible.

GIS: Where Are We Now?

Despite 30 years of development and growth, information on the actual size of the GIS phenomenon is surprisingly difficult to come by. The largest GIS conferences attract many thousands of participants (approximately 5,000 at the 1995 ESRI User Conference), suggesting that the population of GIS users in the U.S. is 100,000, to within an order of magnitude. Figures on numbers of sites from the major GIS vendors suggest that there are a similar number of installed systems worldwide (GIS World Inc. 1996); and the total circulation of the major GIS magazines and total sales of major GIS textbooks are also of the same order of magnitude. Recent figures indicate annual sales by the GIS industry of $500 million (GIS World Inc. 1996). Some 300 vendors list their products in software directories (GIS World Inc. 1996), though not all would meet more rigorous definitions of GIS.

Over the years, GIS has expanded to include significant areas of related disciplines. It is now almost inseparable from cartography, and software for automating cartographic production is often identified as GIS. It overlaps substantially with geodesy, photogrammetry, image processing, remote sensing, land records management, and computer-assisted design. It is now difficult to draw the line between packages for image processing and GIS and similarly between CAD (computer-aided design) and GIS, as vendors have expanded functionality in the gray areas between them.

Today, the term "GIS" means much more than it did 30 years ago, almost defying definition. At its most broad, GIS now refers to any activity involving geographic information in digital form. The convenience of the three-letter acronym has allowed us to give it a meaning of its own that may have little to do with the three words represented. We often hear software referred to as a "GIS system," because GIS now means more than a software system; and we often hear of "GIS data." In fact, GIS can now refer to any combination of software, hardware, data, and communications, and similarly, "doing GIS" can mean building a database, analyzing its contents, making decisions, or plotting maps.

The multiple roots of GIS have been well documented in the earlier chapters of this book. Many threads have converged, from the need to analyze large volumes of natural resource data (Chapter by Tomlinson) and to manage the collection and dissemination of the census (Chapter by Cooke) to the addition of geographic features to systems built for design activities (Chapter by Moyer). GIS remains largely a technology of two-dimensional, static, deterministic data at a single level of resolution. Attempts to build time, the vertical dimension, uncertainty, and hierarchies of generalization into GIS remain largely confined to the research community, although there are excellent products available to link GIS with capabilities in these areas in other systems, and many GIS vendors have made progress in representing hierarchies of objects and in temporal change. But despite these developments, GIS remains largely dominated by the metaphors of maps and images, and many might argue that it should remain so. Whether we will move beyond these limitations is discussed at length in a subsequent section.

Within the limited context of map and image data, GIS is an enormously powerful tool for inventory, query, analysis, and decision-making; the larger vendor systems do almost everything one would ever want to do with geographic information in a digital computer. The number of alternative ways of capturing map and image contents into a digital database provides much of the richness of current GIS but also makes it difficult to transfer data between systems that have taken different approaches or to achieve interoperability. Again, these are topics of active research and are discussed at length later.

The Broader Context

The Computer as Calculator

Although the concept is much older, the first machine we would recognize as a digital computer appeared on the scene almost exactly 50 years ago. ENIAC (Electronic Numerical Integrator and Computer) and its mechanical precursors addressed a particularly simple and well-defined human problem—the need to make great numbers of arithmetic calculations quickly. Although it would have been possible to do so by hand, the economic and social costs of doing so were clearly too severe, and the challenge of building a massive calculating machine was too challenging. Many of the early motivations for massive calculation were digital. In the immediate postwar period, there was heavy demand for predictions of trajectories of assorted ballistic weapons and for solution of the equations governing nuclear fission and fusion (Stern 1981). Consequently, ENIAC was quickly followed by others and by the emergence of a commercial manufacturing industry.

Civilian applications followed. Massive arithmetic computations are needed for weather forecasting to find numerical solutions to the equations governing the atmosphere. They are needed in statistics, in the inversion of large matrices for factor analysis, and in optimization of models in traffic analysis. By the late 1950s, commercially available computers were being installed in major universities to serve an increasingly diverse range of needs. All, however, were driven by the need for a fast calculating machine.

The Computer as Information System

By the advent of GIS, it was becoming apparent to far-sighted followers of the digital computer that something much more significant than a calculating machine was beginning to emerge. Although FORTRAN included the ability to store alphabetic characters in addition to numbers, its main use was in making numerical output easier to read and understand. But if a computer could process text, it could be used to search for particular words or to store messages. By the 1960s, visions of a digital world had begun to emerge (Negroponte 1995). If the computer could store other kinds of information besides numbers, process them, and communicate them to others, then one could begin to imagine a future in which computers allowed a much more comprehensive and adaptable approach to all of society's information needs. Methods to store text, images, and even sound began to emerge in the 1960s, along with terms like "artificial intelligence" that reflect this vastly expanded view of the power of digital computers using metaphors of human reasoning. Early experiments were made in digital communication technology, which offered advantages in much lower error rates and more powerful switching.

Today, we are much more likely to think of computers as information systems than as calculators. The byte became the basis on which to store a full range of alphanumeric characters. Images are stored by allocating a fixed number of bits or bytes to each picture element or pixel. Maps, however, remain more problematic, as there are many ways to capture the contents of a topographic map using concepts of raster or vector storage. Modern database management systems freely incorporate numbers, text, and images but rarely maps except in primitive scanned raster format or in specialized GIS.

Digital Worlds

Today, we encounter digital technology in almost all aspects of our lives. It is used to compose text and print newspapers, to reproduce music, to make maps, to transmit voice messages by wire or radio, and it is about to become the basis of television as well. Digital chips are installed in automobiles, microwave ovens, and even some credit cards. It is difficult now to find any kind of information of value to modern society that is not represented in digital form at some point in its life. Digital computers are now found in a significant proportion of households in the industrial world and are beginning to replace many traditional information resources such as encyclopedias and atlases. Yet while many people are now familiar with digital information systems and regularly use digital word processors and electronic mail, few make use of the computer's power to store, process, and retrieve the contents of maps. In the case of geographic information, digital technology has only just begun to have an impact on our daily lives.

New Societies

With the recent explosion of interest in digital communication using tools such as electronic mail, the Internet, and the World Wide Web, what was once an exotic academic specialty has now become a major topic of public interest. Predictions of a pervasive impact of digital technology on society that were once distributed only among a select handful of futurists are now openly debated, even by politicians (Gore 1993; Gingrich 1995). Open communication between individuals using technologies that are almost impossible for governments to control has been heralded as the essential ingredient of a new democratic age, in which the individual is empowered as never before. Whatever one's reaction to the hype, it is clear that digital information technology is beginning to have an impact on society. It permits a massive redistribution in the geography of employment by supporting telecommuting, and it exacerbates inequities by offering vastly greater opportunity to those who can afford to invest in it.

The previous sections have suggested that the history of digital computing can be organized into four distinct stages. The next sections turn to GIS and trace its development within the same basic framework.

GIS within the Broader Context

The Analytic Engine

As Roger Tomlinson shows in Chapter 2, the design of CGIS was oriented primarily to the analysis of the Canada Land Inventory, a vast collection of data on land resources gathered over a significant fraction of the surface of Canada. The results needed by the provincial and federal sponsors were essentially numeric—totals of land area in various categories—and the computer as calculating machine seemed the only means available to perform the necessary analysis at reasonable cost. Early designs included no facility for map output for two main reasons—the computer-driven plotters of the time were far from reliable and high quality cartography was available as a simple by-product of the input process.

Other early applications of computing to geographic data similarly reflected the thinking of the time (Coppock and Rhind 1991). Computers were introduced to the cartographic production process first as calculators to ease the numerical calculations involved in producing maps as projections of the Earth's surface. The idea of using computers to edit maps came somewhat later after the perfection of coordinate input and output devices, including the digitizer and plotter.

By the 1970s, a dominant concern in the developing field of GIS was how to achieve an efficient and effective representation of the contents of a map other than by primitive scanning. CGIS had exploited the idea of arcs to represent the contents of a natural resource map by creating a digital representation of each common boundary between a pair of adjacent areas. But, in other cases, particularly when areas overlap or do not exhaust the space of the map, it is clearly more efficient to represent areas as separate, independent entities. Many more choices had begun to emerge by the 1970s, prompting the Harvard lab to see format conversion between these alternatives as an important and legitimate function of a geographic information system (Chapter by Chrisman). POLYVRT was the first of these exchange modules and reflected the emergence of a new idea—that GIS would have to be more than automated cartography and analysis if it were to exploit the full power of the digital computer to handle geographic information.

The General-purpose Tool for Geographic Information

Although the term had been coined a decade earlier, it was not until the late 1970s that the idea of a general-purpose processor of geographic information emerged. By then, it was clear that a GIS could: (1) use the digital computer to support a wide range of alternative methods of representation or data models, including raster and vector options; (2) be used to structure such data in a rigorous way to make it easy to share it and communicate it to others; (3) perform a full range of editing, retrieval, and analysis functions; and (4) provide the means to make high quality maps. As we have seen, much of the development work that implemented this vision was performed at a small number of institutions in the 1970s, notably the Harvard lab. By 1980, the vision had become sufficiently clear to justify private sector investment, and a range of new commercial products began to appear.

Database management systems offer generic capabilities for storing, retrieving, and presenting data, So too does a GIS but specifically for geographic data. A user skilled in the use of a DBMS can quickly gain the skills needed to work with a well-structured set of data, using standard methods of access such as SQL (Standard Query Language). As GIS evolved as a general-purpose tool, it began to look more and more like a special kind of database management system for geographic data. Of course, a GIS must have many functions concerned with the registration of its data on the surface of the Earth as well as many specialized functions for visualization and analysis, but nevertheless there are many areas in which the application of principles of database management to GIS leads to greater effectiveness. In the 1980s, strong links developed between GIS and DBMS that continue to evolve today.

GIS as an Intrusive Technology

Today, the number of installed GIS is perhaps 100,000 or at least two orders of magnitude less than the number of home computers in the United States. While digital technology already touches our lives in many ways, the intrusion of GIS is much more limited. If advertising in airline magazines is anything to go by, many of us are about to acquire laptop mapping systems to help us find our way in strange cities, and in-car navigation systems are beginning to appear in rental vehicles. But despite this, GIS remains largely the domain of the professional, in specialized departments of local governments, utilities, resource industries, and

resource agencies. GIS has yet to penetrate everyday life in the way that word processing or spreadsheets have.

Yet the consumer marketplace is in many ways the current frontier of GIS. In-car navigation systems have begun to appear in consumer electronics stores, and global positioning satellite (GPS) receivers are widely used in amateur boating. Mapping software is now available in spreadsheet packages, and digital atlases have begun to appear on CD for home use. Digital maps for the media are now available for sale over the Internet. Perhaps we will see the emergence of a TV shopping channel for digital imagery in the next few years or a digital library of geographic data for use in schools (for an example of a prototype digital spatial data library, see the Alexandria Digital Library project: http://alexandria.sdc.ucsb.edu).

The GIS Society

If there has been much speculation about the social and political consequences of digital technology, the same is probably not true of GIS and the use of digital technology for geographic information. Yet the social implications of GIS are potentially very significant. GIS is now used to support a wide range of decisions, particularly in local government. The computer still intimidates many, and output from a computer is often given far more credibility than it deserves. Undoubtedly, there is in GIS technology the potential for abuse, when results are presented as truth but based on bad data or bad analyses. The computer empowers, and if it is available to only one side in an argument it almost inevitably biases the outcome. As GIS technology becomes more widely available, it is increasingly used by both sides—but the potential for abuse is still there.

GIS is expensive, particularly when the costs of assembling data are taken into account. To date, it tends to have been more widely available to those already in power in society and to have served to strengthen that power rather than diminish or share it. Continued decreases in the costs of hardware and software and vastly greater access to data provide grounds for hope that the eventual effect will be to increase equity in society rather than decrease it, but a continued supply of new innovations available only to those able to afford them casts doubt on this argument. These and other concerns are explored at length in the volume edited by Pickles (1995).

In summary, while four stages have been identified in the growth of digital technology in general, it seems that the current state of GIS is somewhere between the second and third—a general-purpose information technology that has not yet penetrated everyday life to a significant degree. The average person might encounter some aspect of GIS and read about it, but access to its full capabilities is currently limited to professional settings.

The Future of GIS

The previous section identified four stages in the development of digital computing and four associated stages in the development of GIS. It was argued that GIS currently lies somewhere between the second and third stages; the view of GIS as a comprehensive information system for geographic data is being gradually supplanted by a sense that GIS is about to intrude on many aspects of everyday life. The fourth stage, of digital technology driving fundamental changes in society may lie in the future for GIS, but there is little sign of it at present, and many problems remain to be overcome before geographic information is as easy to handle as other kinds of information.

One conclusion from this analysis is that in terms of installed capacity and numbers of users of GIS, we remain at an early point on the growth curve. The mass market for geographic information technologies is probably two orders of magnitude larger than the current largely professional market, although the average investment per installation will clearly be much lower. It may be represented by GPS transponders or navigation systems in every car; by road and street map access through interactive television; by a mass market for digital imagery of local neighborhoods; by map-making capabilities in spreadsheet packages; or by digital atlases in the household. All of these hold great promise for helping to develop a mass market for geographic information technologies.

While the acronym "GIS" has become the central rallying-point in a coalescence of related disciplines and activities, it seems unlikely to persist in the mass-market era, where users are less likely to see a commonality between a digital atlas on CD and an in-car navigation system. In that sense, it has been argued that GIS as an identifiable computer application may disappear, as geographic information is integrated into other forms of data handling. Similar arguments are made about GIS as an information system application. Extensions to standard query languages such as SQL may allow its users to make many of the types of queries now restricted to specialized GIS. Recently, there has been a spate of new collaborative ventures between GIS and DBMS vendors, perhaps in anticipation of a greater blurring between the two areas.

There are other views, however. GIS is now identified with much more than software. It includes data, journals, conferences, educational programs—in short, an entire community. The concerns of the community over training, terminology, concepts, and methods of decision-making will not go away as GIS becomes increasingly integrated with other software. The term "geographic information science" has been coined to describe a discipline concerned with the deeper common issues arising from the digital handling of geographic information (Goodchild 1992a), and a University Consortium for Geographic Information Science has been formed recently in the U.S.

In the early days of GIS, the lack of sufficiently powerful computer hardware was critical. CGIS developed in an era when map scanners were unknown, and the cost to the project of developing one on an experimental basis was far higher than the cost of a scanner today, even after allowing for inflation (Chapter by Tomlinson). By the 1970s, the appropriate peripherals had become available along with vastly increased computing resources, and attention switched to the development of necessary software and data structures (Chapter by Chrisman). The 1980s were an era of great improvement in communication technology and infrastructure, allowing distributed GIS databases to function together as if located in one place. Client-server architectures developed in the 1980s, also in response to vastly improved communications, exemplified by the Internet.

Today, technology allows us to consider the possibility of sharing digital geographic information over integrated, worldwide networks, using such Internet services as the World Wide Web. But while sharing is possible in principle, in practice it is severely impeded by the lack of appropriate methods and tools for describing data. Thus, issues of data access may be the most important issue for the 1990s. They are discussed at length below.

Directions in GIS

This section examines emerging development directions in GIS from three perspectives: data models, data access, and the data life cycle. All three focus on data rather than on analysis or modeling, reflecting a tendency in the field to see data issues as of particular significance at this point in the history of the technology.

Data Models

A data model is defined as the set of entities and relationships used to build a representation of some real-world phenomenon in a digital computer (Goodchild 1992b). Geographic data modeling is particularly complex because of the large number of options available. Any GIS implements some combination of the available models, but variations between systems, particularly in terminology and in the particular combination implemented, create major difficulties for users wishing to transfer data from one to another. At the simplest level, the models fall into two categories—raster and vector—though the story is actually much more complex.

Three broad classes of geographic data models are implemented in current GIS (Goodchild 1992b). The first conceptualizes the world as an empty space littered with discrete point, line, or area objects. Any point in space can be occupied by any number of objects, since objects are allowed to overlap and do not normally fill the space. Objects fall into different classes depending on their topological dimensions (zero, one, or two for points, lines, and areas respectively) and on their semantic meaning. These discrete object data models are often found in brands of GIS that have evolved from CAD systems.

In the second class are the field models. Here, the world is conceived as describable by a finite number of variables or fields, each of which has a single value at every point in space. There are five ways of representing fields implemented in GIS: as rasters of cells; as grids of regularly spaced points; as triangular meshes; as digitized contours; and as randomly located points. Examples of each can be found in traditional methods of sampling fields, but not all are implemented in every GIS. A raster GIS, for example, typically implements only the first two.

The third class of data models is made up of those used to represent continuous or discrete variation over networks in applications such as transportation or hydrology. In such cases, the network forms a connected one-dimensional space embedded in two dimensions, and geographic phenomena are confined to the network itself.

Current research in GIS seeks to generalize these basic data models in five ways, each reflecting the need to overcome a constraint inherited from the world of maps and images. The first is time, which may affect the contents of a database through changes in attributes, changes in the positions and shapes of objects, or changes in entire fields (Langran 1992). Temporal information is crucial for many GIS applications, and yet most GIS provide no explicit tools for dealing with it. The second is the vertical dimension and the need to generalize from two-dimensional data models in order to handle applications in geology, atmospheric science, and oceanography (Turner 1992). Although many GIS allow a third coordinate to be added, much more comprehensive solutions are needed to represent three-dimensional fields and volumes.

The third generalization is concerned with scale, since traditional GIS contains few tools for moving between scales and handling data at multiple levels of geographic generalization. In the case of fields, generalization is often implemented as a form of filtering, but in the case of discrete objects much more complex methods are needed to emulate the work of a cartographer (Muller, Lagrange, and Weibel 1995). A multiscaled GIS would also work with hierarchies of objects, in which a single object at one scale was explicitly linked to multiple objects at larger scales. Such methods of complex object representation exist in some GIS but not in others.

The fourth generalization is concerned with the curved nature of the Earth's surface. Maps and images must be flat, and we have developed complex systems of map projections to allow us to represent the Earth's surface in hard-copy form. But in the digital computer there is no need to flatten the Earth, except when making paper maps. Although the screen of a computer monitor is almost flat, sophisticated methods of visualization are already used to create the impression of a three-dimensional solid in the mind of the user. This is particularly easy if the solid can be manipulated by the user. Yet our methods of analysis, modeling, and representation are dominated by the need to emulate the handling of flat maps and images, and we do not yet have a complete suite of methods for working with the surface of the planet. This is unfortunate, because it means that the products of GIS are frequently distorted (Willmott, Robeson, and Feddema 1991).

Finally, the fifth generalization of GIS data models is concerned with the handling of uncertainty. Like the previous four, the lack of explicit methods for representing and handling uncertainty in GIS is inherited from map tradition. Recent research has led to effective methods for modeling uncertainty, capturing it in databases, visualizing it in displays, propagating its effects during analysis, and reporting its consequences to the user (Hunter, Caetano, and Goodchild 1995). Hopefully, future generations of GIS will have the tools available for explicit and objective analysis of the uncertainty present in almost all geographic information.

These five generalizations are not equally important, and it will probably not be feasible to support all of them in GIS, at least in the near future. All five are already supported to some degree in computer software, and there has been steady progress over the past decade in integrating such software with GIS through common interfaces and other kinds of linkage. Three-dimensional applications, for example, can now be supported by linking GIS to specialized 3D packages, and data can be exchanged through a common two-dimensional interface. How many of the five can be supported in GIS itself remains to be seen, and important questions remain about the appropriate balance between feasibility and priority, which are the most important generalizations and what will it take to expand current products by extending their data models?

Data Access

Much effort in the research community is currently being directed to problems of data access. Many of these are institutional, concerned with issues of copyright, intellectual property, protection of privacy, and confidentiality (Onsrud and Rushton 1995). Others are more technical and concerned with the techniques available to describe data, transfer it from one system to another, find it across the worldwide network, and share it effectively.

The term "metadata" is often used to refer to the descriptive material needed if data is to be effectively shared. It includes information analogous to a catalog record for a book—subject, title, author—as well as information needed to make the data readable, such as its format. Metadata also includes information needed to handle the data successfully, such as file names. Finally, it includes information on the data's quality, to help the user assess its fitness for use.

Metadata is not merely a description of data but a means of communication about data from the custodian to the potential user. As such, it must reflect not only the properties of the data but also the level of expertise of the user, and it must be expressed in terms whose meaning is known to the user. The more successful a metadata description, the more it will be possible to share data beyond the limits of the discipline of the custodian or creator. Thus metadata is the key to realizing the value invested in data, by extending its use to the widest possible community.

In 1995, the Federal Geographic Data Committee published its Content Standard for Geospatial Metadata, an attempt to provide a standard framework for GIS metadata. It has been widely studied and adopted, and similar standards are being developed by other U.S. jurisdictions and in other countries. Metadata handling is being added to many GIS software products, with the result that it will soon be possible to access and display metadata, to use it to provide automatic control of processes where appropriate, and to process it automatically when a data set is changed by a GIS process.

Concern for spatial metadata is only one part of a broadly based effort to improve access to geographic information. The Alexandria Digital Library (http://alexandria.sdc.ucsb.edu) is a research project dedicated to the development of services on the Internet analogous to those provided by a map library but without the latter's physical access limitations. Alexandria uses the power of the digital environment to overcome many of the traditional impediments to the handling of maps and images in the library. For example, geographic location is used as the basis for an additional search and browse capability, in addition to the traditional subject, author, and title.

GIS in the Data Life-cycle

One legacy of the first era of computer technology discussed earlier has been the view that GIS's primary purpose is the analysis of existing data, in support of modeling, prediction, and decision-making. Many GIS projects have been built around existing sources of data in map and image form. But analysis is only one stage in the life cycle of geographic data, which extends from field data collection through compilation, interpretation, classification, and digitization to final archiving. As a technology for handling geographic data, GIS has the potential to play a role in all of these stages. The previous section's discussion of metadata, for example, can be seen as an extension of GIS technology into a broader concern for data access mechanisms.

The recent development of portable and hand-held computer hardware opens the potential for GIS support of field data collection to a much greater extent than has been possible in the past. With appropriate functionality, such systems can support acquisition of field knowledge by providing capabilities for capture of a broad range of types of information onto a preloaded base, such as an ortho-rectified digital image. GPS and digital cameras allow other important types of geographic information to be acquired and stored directly in the GIS database. Technologies such as this may help open the channel of communication between the field scientist and the analyst.

Modern computer technology allows far more than raw data to be communicated. Object-oriented concepts of encapsulation allow processes to be coupled with data, suggesting that the field scientist of the future might be able to specify the operations that make sense for data and thus help the eventual user understand the data's meaning.

Conclusion

There seems little doubt that the early efforts to develop GIS documented in the chapters of this book have paid off and will continue to do so as GIS expands both in capabilities and in applications. Whether or not GIS continues to be the appropriate umbrella term, geographic information technologies clearly have an increasing role to play, both in the professional workplace and in everyday life. The GIS research community will continue to find ways of getting around the impediments presented by current GIS and solving the issues that underlie its use.

Histories are normally written after the events they describe have receded sufficiently in time to dull their impact. In that sense, this history of GIS may be premature, because even the earliest developments in the field continue to have an influence on ways of thinking about GIS and on the technology we see today. Both GIS and GPS were being designed and researched 30 years ago, and yet both are only now beginning to impact everyday life. Although many might see GIS as an overnight sensation, it is the cumulative efforts described in these pages that have allowed this immensely complex and challenging computer application to reach the stage it is in today. Many problems remain to be solved as GIS struggles to become easier to use through efforts to build better user interfaces and to make the products of different vendors interoperable (http://www.regis.berkeley.edu:80/ogis/) by taking advantage of wider trends in the computer industry towards open standards. The results of these efforts will be seen in the next generation of GIS products and will be recorded the next time the history of GIS is written.

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