INTEROPERATING GEOGRAPHIC INFORMATION SYSTEMS

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INTEROPERATING GEOGRAPHIC INFORMATION SYSTEMS

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PREFACE

Since the first commercial products became available around 1980, geographic information systems (GISs) have become a significant area of application of computing technology. They developed in response to practical needs, in the handling and analysis of digital geographic information, and without any strong theoretical framework. As a result, the GIS software industry that exists today is fragmented: each vendor has adopted a distinct terminology and approach; a technician trained on one GIS has a difficult time adapting to a different one; and a database built for one system is not necessarily usable in another. Just as the science of statistics provides a common mathematically-based language and framework for much statistical software, so a strong theoretical framework in geographic information science can provide principles and terminology for an easier-to-use, more coherent, and more *interoperable* GIS industry. The research community has made great strides in recent years in developing that fundamental theory, building on work in computer science, cognitive science, linguistics, information science, applied mathematics, and statistics. At the same time data sharing, exchange, and integration in GIS have become significant issues, where progress offers substantial benefits in reduced costs, increased flexibility, and speedier projects. This book captures the state of progress, places it in the context of fundamental theory, and expands on the institutional implications of greater interoperation among GISs.

Interoperation means many things to people. It means *openness* in the software industry, because open publication of internal data structures allows GIS users to build applications that integrate software components from different developers, and it allows new vendors to enter the market with competing products that are interchangeable with existing components, just as the concept of interchangeable parts helps competition in the automobile industry. In the past few years the Open GIS Consortium (OGC) has emerged as a major force in the trend to openness, as a consortium of GIS vendors, agencies, and academic institutions (*http://www.opengis.org*). Interoperation also means the ability to *exchange* data freely between systems, because each system would have knowledge of other systems' formats. Exchange standards such as the Spatial Data Transfer Standard (also known as Federal Information Processing Standard 173; Arctur et al. 1998) have had a significant impact on the ease with which data can be transferred between systems. They allow a user of one vendor's products to make use of data prepared using another vendor's products, because data can be transferred in a standard format. Interoperability also means *commonality in user interaction*, as system designers build interfaces that can be customized to a 'look and feel' familiar to the user.

Simplification is a common theme in discussions of interoperability—simplification in the complex collections of formats and standards in the industry, simplification in the interaction between user and system, simplification in the knowledge a user requires to be effective. In an interoperable world the user would have to *know less* in order to achieve the same outcome. Training on ARC/INFO would not be wasted if the user transferred to an Intergraph platform, and there would be no need to master the complex details of data formats in order to assemble a project database from different sources. From an educational perspective, progress in interoperability would be measured by what it was no longer necessary to teach.

The term *transparency* is used when a user no longer needs to be aware of the details of a computer implementation to use it effectively. A database management system offers transparency to its users, who need to know nothing about the actual implementation of a data model, or about the physical locations of data and software, but can work instead at a conceptual level. Transparency implies that certain things are no longer important to the user, and no longer intrude upon the user's conceptualization of the problem. It implies a uniform view of multiple, heterogeneous, distributed, and autonomous participating systems.

Another term with particular relevance to interoperation is *similarity*, a measure of the degree to which two data sets, software systems, disciplines, or agencies use the same vocabulary, follow the same conventions, and thus find it easy to interoperate. Currently, interoperation is possible only over the narrowest of domains. The effort to achieve interoperation is thus an effort to extend domains, or to raise the threshold of similarity below which interoperation is possible.

The current architecture of GISs requires its users to be specialists, who must learn a terminology that is largely system-specific, a user interface that is similarly dominated by details of implementation, and a world of data that is riddled with convention. In order to make use of today's GIS one must be a *spatially-aware professional* (SAP). The ability to decode acronyms is one of the tests of an SAP, who must know, for example, the meaning of all of the Dxx acronyms—DEM, DTM, DLG, DRG, DOQ, DCW (digital elevation model, digital terrain model, digital line graph, digital raster graphic, digital ortho-photo quadrangle, digital chart of the world respectively)—and their general characteristics. SAPs hold much of the *metadata* of the common data sets in their heads, and thus are able to locate necessary data and assess their fitness for use without use of the apparatus normally required to support information retrieval, such as directories, catalogs, and libraries. SAPs will have taken courses in GIS, or may have acquired their awareness through the use of software, attendance at conferences, or from the published literature.

SAPs know the conventions of the geographic information community, and its language. They know, for example, the conventions that allow the producers of DOQs to assert that the representative fraction of their product is 1:12,000 (Goodchild and Proctor 1997). This has no relationship to representative fraction as normally defined for paper maps, since there is no distance in a digital database that can be compared to distance on the ground. Rather, a DOQ has a scale of 1:12,000 because its positional accuracy, which is well-defined, matches that of a map at that scale, according to national map accuracy standards (*http://mapping.usgs.gov/www/ti/DOQ/doqpt1.html*).

Perhaps most importantly, SAPs know the conventions of GIS discretization, which maps real-world objects and fields to their digital equivalents. The object conceptualized by a user as a continuous line is discretized as a *polyline*, consisting of mathematically straight connections between discrete points. Similarly, by convention an area is discretized as a *polygon*, and may even be referred to as such by an SAP. A field is discretized in many different ways that are embedded within distinct suites of software. Thus the same concept, a continuous surface of elevation, that is widely understood across many disciplines and professional cultures, may be represented in GIS as a TIN (triangulated irregular network, or triangular mesh), the digitized contours of a DLG, or the regular grid of a DEM. While the conceptual schema is the same, the implementations are entirely different, and are never hidden from the GIS user, ensuring that GIS is essentially inaccessible as a tool to anyone other than an SAP. Vckovski (1998a) has argued that an interoperable world would have just one conceptualization of a continuous surface, and that many aspects of the actual implementation can be made transparent to the user.

Interoperability conceived in this way is clearly relevant at many levels (see, for example, the collection of papers edited by Vckovski 1998b), and in many different aspects of GIS. Many different types of detail can be made transparent to the user, and many aspects of implementations can be hidden. Efforts are needed on many fronts, and many conceptual and technical problems will have to be solved, before much progress can be made towards the goal of interoperability. That progress might be measured by ease of use, represented by the amount of training needed to accomplish a certain task, or by the number of user actions required. It might be measured less directly in terms of redundancy of instruction, as items in the GIS curriculum that now must be covered before students can make effective use of GIS become redundant, or at least relegated to classes that focus on the technical details of GIS, rather than its applications. Other suitable metrics might be based on the transferability of knowledge, measuring the effort required by someone trained on System A to achieve the same productivity on System B. Progress might also be measured by comparing across disciplines, or application domains.

Many recent developments in information technology and GIS are immediately and obviously relevant to interoperability, either by motivating interest in achieving its objectives, or by providing the technical means to do so. The Internet and its applications, particularly the World Wide Web (WWW), are driving much of the interest in interoperability, because they make transfer of data and software possible, but fail to resolve many of the more difficult issues that transfer raises. Developments in distributed systems, client–server architectures, digital libraries, and other related areas are also high on the technical agenda at this time, as the contents of this book make clear.

The idea of a book on Interoperating GISs arose from an initiative of the U.S. National Center for Geographic Information and Analysis (NCGIA), a consortium of the University of California, Santa Barbara; the University at Buffalo; and the University of Maine; and under the auspices of its Project Varenius, NCGIA's project to advance geographic information science. Varenius is funded by the U.S. National Science Foundation through Cooperative Agreement SBR 9600465. NCGIA sponsored an international conference on interoperating GISs, Interop '97, in Santa Barbara in early December 1997, and held an invitational workshop immediately following the conference to develop a research agenda in the field. The results of that workshop are available as a printed report and on the WWW (Goodchild et al. 1997). Following the conference, the authors of the papers judged best by the conference program committee were invited to submit expanded versions for this book.

The book is divided into four major sections. In the first, Max Egenhofer introduces the need for theory, and nine chapters that present various theoretical frameworks. The second contains six chapters on modeling in distributed environments. In the third section, Cliff Kottman introduces a series of chapters on prototypes and functional systems, and on the lessons learned from them. In the final section, Robin Fegeas introduces a set of chapters on the institutional context of interoperation, issues of electronic commerce and GIS, and education.

The editors hope that this book will lay a firm foundation for research on interoperating GISs, and help push the field towards a more coherent, simpler, and more integrated future. We thank all of the authors for their contributions, and especially the National Science Foundation and the Open GIS Consortium for their collaboration in making this effort possible. Many of the software, system, and corporate names that appear throughout the book are registered as trade marks or otherwise protected.

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