GIS Best Practices

Essays on Geography and GIS: Volume 2

July 2009

Table of Contents

What Is GIS?

Making decisions based on geography is basic to human thinking. Where shall we go, what will it be like, and what shall we do when we get there are applied to the simple event of going to the store or to the major event of launching a bathysphere into the ocean's depths. By understanding geography and people's relationship to location, we can make informed decisions about the way we live on our planet. A geographic information system (GIS) is a technological tool for comprehending geography and making intelligent decisions.

GIS organizes geographic data so that a person reading a map can select data necessary for a specific project or task. A thematic map has a table of contents that allows the reader to add layers of information to a basemap of real-world locations. For example, a social analyst might use the basemap of Eugene, Oregon, and select datasets from the U.S. Census Bureau to add data layers to a map that shows residents' education levels, ages, and employment status. With an ability to combine a variety of datasets in an infinite number of ways, GIS is a useful tool for nearly every field of knowledge from archaeology to zoology.

A good GIS program is able to process geographic data from a variety of sources and integrate it into a map project. Many countries have an abundance of geographic data for analysis, and governments often make GIS datasets publicly available. Map file databases often come included with GIS packages; others can be obtained from both commercial vendors and government agencies. Some data is gathered in the field by global positioning units that attach a location coordinate (latitude and longitude) to a feature such as a pump station.

GIS maps are interactive. On the computer screen, map users can scan a GIS map in any direction, zoom in or out, and change the nature of the information contained in the map. They can choose whether to see the roads, how many roads to see, and how roads should be depicted. Then they can select what other items they wish to view alongside these roads such as storm drains, gas lines, rare plants, or hospitals. Some GIS programs are designed to perform sophisticated calculations for tracking storms or predicting erosion patterns. GIS applications can be embedded into common activities such as verifying an address.

From routinely performing work-related tasks to scientifically exploring the complexities of our world, GIS gives people the geographic advantage to become more productive, more aware, and more responsive citizens of planet Earth.

GIS: Designing Our Future

By Jack Dangermond

"Man may perish by his own explosive and insidious inventions. For an adjustment to them he leaves himself precious little time, and progressively less as his technological wizardry runs wild and rushes on. If he is to survive at all, it cannot be through slow adjustment. It will have to be through design more subtly considered and circumspect, through more cautious planning in advance."

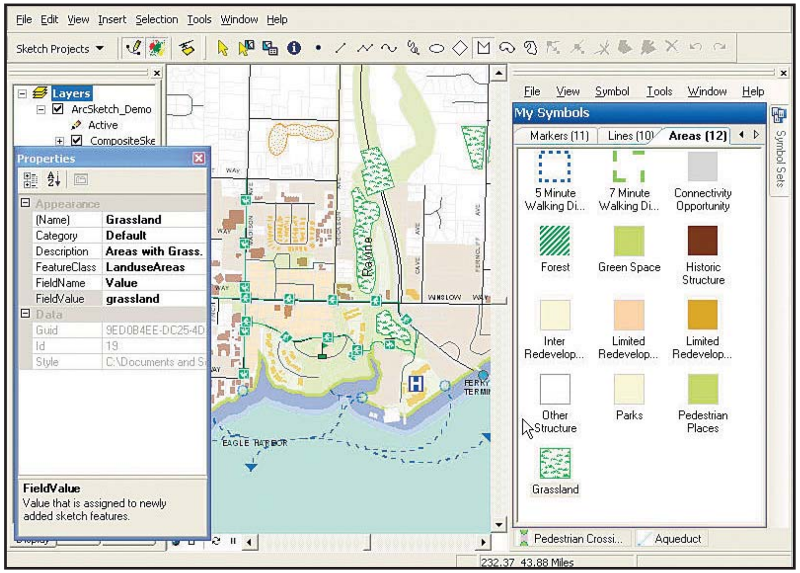
With those words in 1954, influential architect Richard Neutra opened his seminal book *Survival through Design.* Neutra was an early environmentalist, taking an approach to architectural design that applied elements of biological and behavioral science—what he called biorealism, or the "inherent and inseparable relationship between man and nature." Fifteen years later, in his groundbreaking book *Design with Nature,* landscape architect Ian McHarg advocated a framework for design that helps humans achieve synergy with nature. Design and planning that take into consideration both environmental and social issues help us ensure that our resources are used appropriately and responsibly, to help us move toward a better future for all. McHarg's pioneering work not only had a fundamental influence on the up-and-coming field of environmental planning but simultaneously solidified the core concepts of the young field of GIS as well.

In the 40 years since *Design with Nature* was written, a better world is the common goal all of us—geographers, planners, scientists, and others—have been striving for. Discussing his book during the Keynote Address at the 1997 ESRI International User Conference, McHarg laid out a process by which "environmental data could be incorporated into the planning process." Rejecting the view of a future modeled after some idyllic environmental past, he instead was an early adopter of the view that we should be using our dominance of earth systems to help evolve the natural world and make it better, rather than conquer it. Powerful anthropogenic influence over earth systems represents not just a huge challenge but an equally huge opportunity—not humans versus nature, but humans with nature. "While traditional ecological research selected environments with a minimum human influence, I selected arenas of human dominance," McHarg said. Today more than ever, it is important to recognize the overwhelming impact of humans on the environment, that massive human impacts on the earth are a fact that's not going away, and that we stand at the crossroads. Thus, our challenge is to provide designers, engineers, planners, and others, with a set of tools and a framework for designing and managing the anthropogenic earth.

Design for the Anthropogenic Earth

I've recently become very interested in the relatively new field of earth systems engineering and management (ESEM), which concerns itself with the design, engineering, analysis, and management of complex earth systems. ESEM takes a holistic view of multiple issues affecting our earth—not only taking environmental, social, and other considerations into account up front in the design process but also looking at challenges from an adaptive systems approach, where ongoing analysis feeds back into the continual management of the system.

Braden Allenby, professor of civil and environmental engineering at Arizona State University and one of ESEM's founders, often emphasizes the undeniably dominant role humans have in earth systems. "We live in a world that is fundamentally different from anything that we have known in the past," says Allenby in his paper "The Metaphysics of the Anthropogenic Earth Part I: Integrative Cognitivism." "It is a world dominated by one species, its activities and technologies, its cultures, and the integrated effects of its historical evolution." McHarg was already moving in this direction in the 1960s, and today we understand that it is even more important to emphasize the anthropogenic elements of earth systems. In other words, at this stage of ecological evolution, humans are a significant, if not dominating, component of the natural environment, and all problems need to be addressed and decisions made with anthropogenic elements in the forefront.



ArcSketch tool-style editing in ArcGIS 9.4 will make editing simpler.

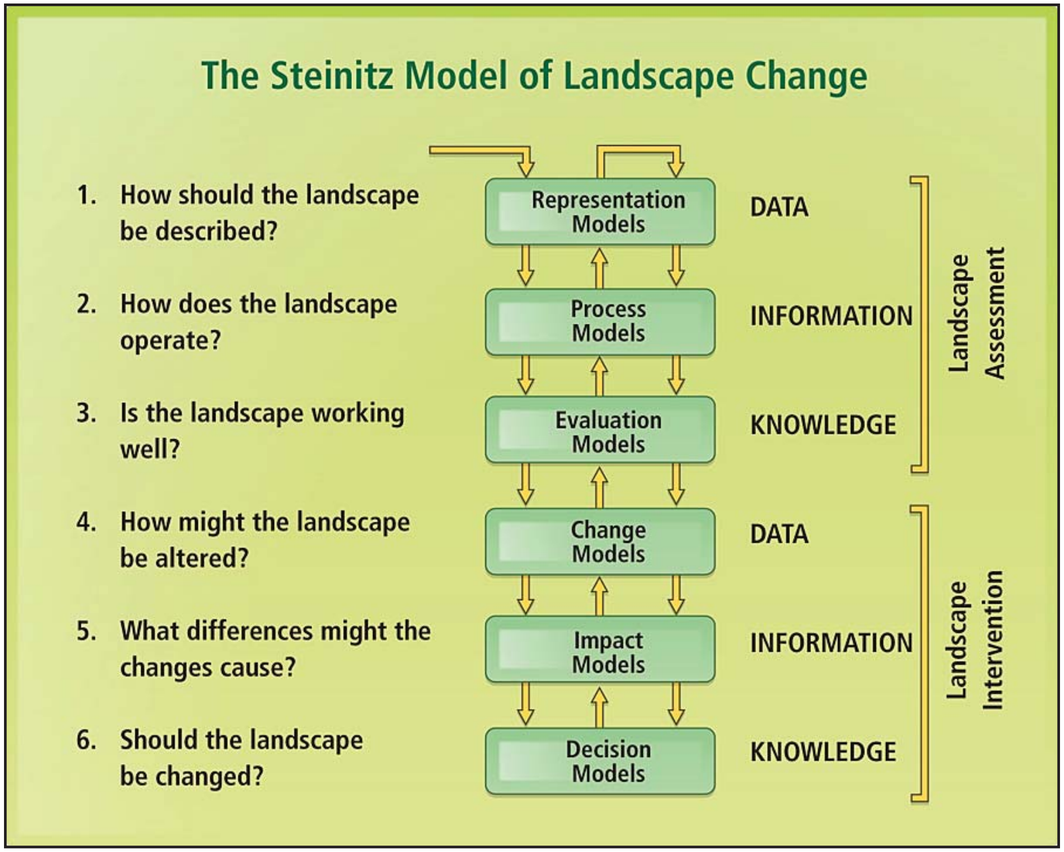
Allenby sees reasoned design and management in the age of the anthropogenic earth as our moral imperative, but the biggest obstacle to our success is that we are not set up to work, or even think, in this way. "We lack solid data and analytical frameworks to make assertions about the costs, benefits, and normative assessments of different . . . practices," notes Allenby in "Biomass Management Systems" in *Reconstructing Earth.* And this is why I believe that GIS and the emerging field of GeoDesign are critical to the success of approaches such as ESEM and other logical and rational models for dealing with the environmental and planning problems of ours and future generations.

"We are being propelled into this new century with no plan, no control, no brakes." —Bill Joy, Cofounder and Chief Scientist, Sun Microsystems

Designing Alternative Futures

The key to developing a true understanding of our complex and dynamic earth is creating a framework to take many different pieces of past and future data from a variety of sources and merge them in a single system. GIS is a sophisticated technological tool already in widespread use by planners, engineers, and scientists to display and analyze all forms of location-referenced data about the health, status, and history of our planet. GIS enables a GeoDesign framework for analyzing and managing anthropogenic earth issues by allowing users to inventory and display large, complex spatial datasets. They can also analyze the potential interplay between various factors, getting us closer to a true understanding of how our dynamic earth systems may change in the coming decades and centuries.

Carl Steinitz, an urban planner at Harvard University, originated many of the early ideas about the application of GIS for landscape analysis and urban planning. Steinitz developed a model of landscape change that enables design of alternative futures. Those alternative designs can then be evaluated in terms of their impact on the natural environment as well as their utility to the human population, and the alternative future that is projected to achieve the best balance can then be selected for implementation. With a debt of gratitude to Steinitz ("A Framework for PLF," *Landscape Future*), the GeoDesign framework also lets us design and test various alternatives, helping us make the most educated and informed decisions about the best possible future.



Is the earth getting hotter or colder? Is the stress human populations are putting on the planet contributing to climate change? What potential factors may significantly impact our ability to thrive and survive in the future? What additional sorts of environmental monitoring can we be doing today to improve decisions in the future? We are only beginning to understand how to approach these questions, let alone come up with scientifically valid answers. Only through careful observation of the data, application of scientific principles, and using GIS and other technologies do we have any hope of truly understanding the stressors and impacts on the incredibly complex systems that comprise our anthropogenic earth. It's also the key to making pragmatic, thoughtful, informed design decisions and proposing alternatives that allow humans and nature to coexist more harmoniously.

Design with Nature

Design with Nature—rarely has a three-word title so eloquently summed up an entire tome. The most important word in that title is not *design,* nor is it *nature.* It's *with.* It sets the stage for design and nature working together in concert to achieve something that is bigger than the sum of the parts, a synergy of design and nature reaching toward the goal of the survival of the human species in particular and the planet in general.

It's not a stretch to say that the development of GIS technology and the entire industry around it was profoundly influenced by the work of McHarg. He popularized the overlay concept and laid the groundwork for what was to become GIS, thus taking a number of budding young landscape architects and geographers and changing their lives forever.

McHarg and I may have disagreed on some things, but we clearly shared the vision of using geographic analysis techniques to design a better world. Although we've made much progress in building the infrastructure to help us accomplish this monumental task, we're still not quite there yet. In fact, 28 years after *Design with Nature* was published, McHarg issued a challenge of sorts to attendees of the 1997 ESRI International User Conference in his Keynote Address:

"By and large, the ecological planning studies I did in the 1960s and 1970s have not been equaled, far less surpassed. And I think there has got to be a challenge; that is, we've got to be able to learn to do at least as well for regions and for the nation and, indeed, for the global environment as we are doing at the moment."

Like McHarg's *Design with Nature,* ESRI is also celebrating its 40th anniversary this year. It's no coincidence that both the concepts espoused within *Design with Nature* and the GIS work led by ESRI launched almost simultaneously. When McHarg advocated this new methodology of taking geographic considerations into the design process and workflow, I don't know if he could ever have imagined how far we'd come with GIS by 2009. But the hard work we've been doing on developing GIS technology for the last 40 years does not mean we are finished, or even close to being finished. And I feel that all our hard work evolving GIS has led us to this pivotal point. The next logical step in the evolution of this technology is GeoDesign.

The Case for GeoDesign

GeoDesign borrows concepts from landscape architecture, environmental studies, geography, planning, regenerative studies, and integrative studies. Much like GIS and environmental planning before it, GeoDesign takes an interdisciplinary, synergistic approach to solving critical problems and optimizing location, orientation, and features of projects both local and global in scale.

Design is art within the framework of limitations—limitations that arise as a result of function, world view, bias, and other factors, but also limitations that arise as a result of place. Design considering place was at the core of McHarg's beliefs, and it is the basis for our research and development efforts in the emerging field of GeoDesign.

". . . design is always and necessarily an art as well as a problem-solving activity . . ." —David Pye, The Nature of Design

To a certain extent, this is already done today by numerous GIS practitioners in fields like urban and regional planning and environmental management. But GeoDesign makes this easier by making it an integral part of the workflow, both shortening the cycle time of the design process and improving the quality of the results.

Cycle time is shortened because GeoDesign moves analysis to an earlier stage in the design process. Rather than analyzing the potential impacts and effects of a proposed project after the design phase, critical factors are instead taken into consideration up front. The quality of the results improves because the project is designed around, in concert with, and/or to fully leverage certain geographic, environmental, and social features while simultaneously minimizing undesirable impacts to those same features.

Designing Our Future

"GIS: Designing Our Future" is the theme of the 2009 ESRI International User Conference. When I talk of designing our future, I believe that combining the wealth of data available about our world with sophisticated analysis and management tools is the prescription for understanding and shaping the future of our planet—an anthropogenic future where advances in human society, technology, etc., are designed in close collaboration with nature, resulting in the best of possible future worlds. It's a huge task and a delicate balance, for sure, but with help from GIS and GeoDesign tools, we readily accept that challenge. Because, frankly, we have no other choice.

What Is GeoDesign?

GeoDesign brings geographic analysis into the design process, where initial design sketches are instantly vetted for suitability against a myriad of database layers describing a variety of physical and social factors for the spatial extent of the project. This on-the-fly suitability analysis provides a framework for design, giving land-use planners, engineers, transportation planners, and others involved with design, the tools to leverage geographic information within their design workflows. Fully leveraging geography during the design process results in designs that emulate the best features and functions of natural systems, benefiting both humans and nature through a more peaceful and synergistic coexistence.

GeoDesign involves three activity spaces: the work environment (where designers do their work), the design tools (the tools designers use to do their work), and supportive workflows (how designers do their work). Having one of these out of sync can impede the design process.

- Work Environment—Today's work environment used by geo-based design professionals involves the field, the desktop, connection to enterprise servers and databases, the use of document management systems, collaborative environments (both inside and outside the enterprise), and interaction with outside agencies and organizations.
- Design Tools—Geo-based designers use a variety of tools to assist them as they create their designs. Probably the most frequently used tool, or type of tool, is the drawing tool. The particular type of drawing tool depends on the designer's domain and whether the designer is working in 2D or 3D space.
- Supportive Workflows—Most geo-based workflows, at least at a detailed level, are domain specific. Three workflows pertaining to the use of geographic information stand out, however, as being predominantly genetic: one related to land-use change; one related to the design, construction, and management of built facilities; and one related to the use of 2D CAD.

Early Forays in GeoDesign

Although it might be easy to compare the two, GeoDesign should not be confused with computer-aided design (CAD). In fact, the first geographic design system was ArcCAD, ESRI's earliest attempt to build a dedicated GeoDesign tool. Released in the early 1990s, ArcCAD was the first fully functional GIS system within the AutoCAD environment. While traditional CAD is a useful tool in the architectural design of a building, GeoDesign is concerned with designing that same building in and around the environment. ArcCAD was an attempt to integrate geographic data and spatial modeling into the design process. ArcCAD provided powerful mapping, data management, spatial analysis, and display tools that worked directly with AutoCAD's design and drafting tools.

ArcCAD was followed by other ESRI applications (including SDE CAD Client and ArcGIS for AutoCAD) that allowed designers and others within the CAD environment to leverage the full power of GIS functionality and GIS databases. ArcGIS for AutoCAD, a free downloadable tool that offers seamless interoperability between AutoCAD and the ArcGIS platform, is used widely today. ArcGIS for AutoCAD users are provided with quick and easy access, within the AutoCAD environment, to enterprise GIS data published by ArcGIS Server. This tool lets designers include the results of GIS analysis in AutoCAD designs, as well as create, manipulate, and define how CAD data is organized and attributed as GIS content.

Design Tools in ArcGIS

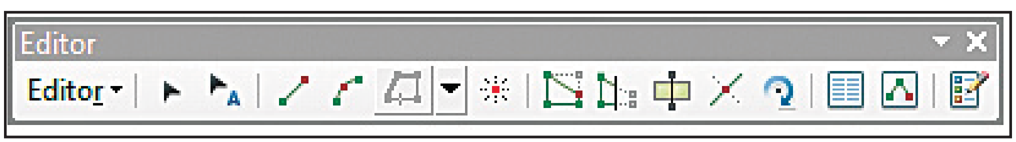
Design professionals are creative and rely heavily on intuition, a gut feeling that something is right. GIS professionals providing input to a creative process rely heavily on analysis and science. With GeoDesign, GIS becomes a tool for designers; they can move rapidly through an iterative design process while leveraging the full analytical power of the geodatabase. We believe that bringing together the worlds of design and analysis under one common information system framework will have huge implications.

In 2005, Bill Miller, ESRI's engineer/architect, led a small team to develop a free sample ArcGIS extension that was the first step toward true GIS-based GeoDesign tools. Released in 2006, the extension allows you to quickly create features in the ArcGIS Desktop ArcMap application with easy-to-use sketch tools. You simply select a sketch tool and an associated symbol, then draw the feature. This simple design tool automatically manages the drawing environment, allowing you to conceptualize what to draw, as opposed to how to draw it. With ArcSketch, you can sketch a set of alternative land-use concept plans, quickly lay out the spatial components of a disaster response plan, sketch out the location of a highway, or lay out a site master plan.

As a geographic sketching tool that allows users to sketch initial designs on top of GIS-based maps and imagery, ArcSketch was useful to many of our users, but it is only the beginning. Functionality similar to ArcSketch will be further enhanced and integrated into the core software system at the 9.4 release. And subsequent releases of ArcGIS promise even more support for the use of GIS for design.

ArcSketch tool-style editing in ArcGIS 9.4 will make editing simpler, with new streamlined functionality making it easier for you to complete your work.

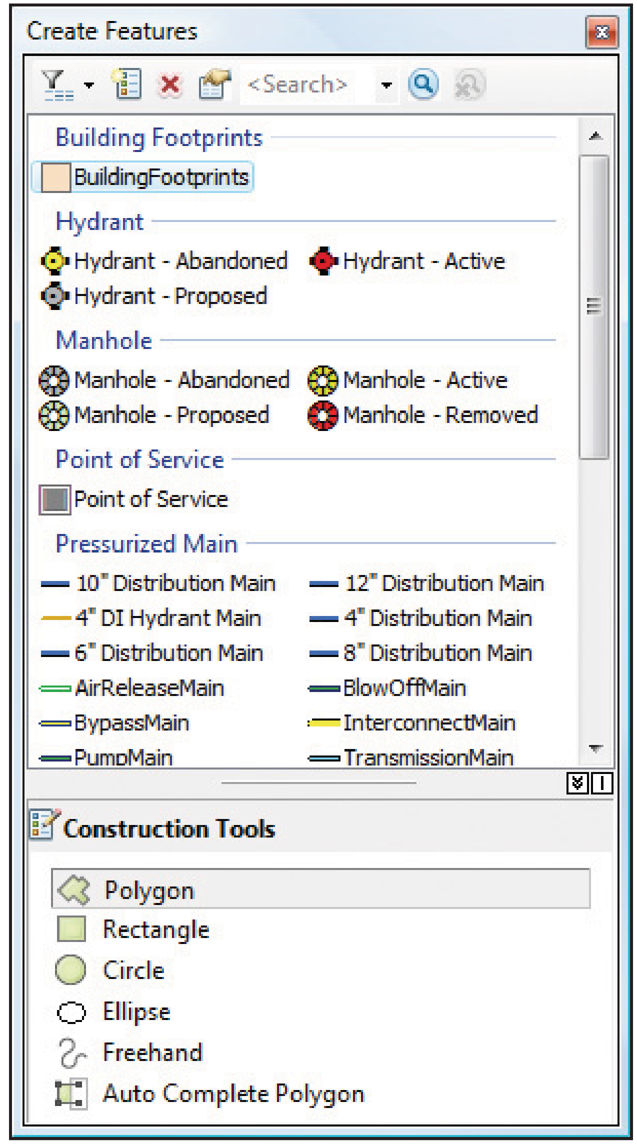
Creating features is accomplished through the use of feature templates. To get started with templates, you just need to start editing, which launches the Create Templates wizard. The wizard will quickly help you build a set of feature templates you can use to create new features. Once you finish, the Create Features window opens with a list of templates.



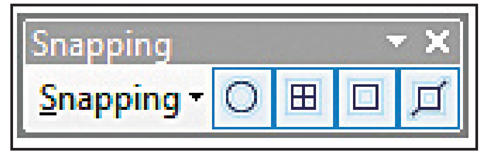
Feature templates define all the information required to create a new feature: the layer where a feature will be stored, attributes new features will be created with, and the default tool used to create that feature. In the Create Features window, choose the template in which to store the new feature, click a construction tool from the palette at the bottom of the window, and click the map to digitize the shape of the feature. In ArcGIS 9.4, the edit sketch will show a WYSIWYG preview with the symbology used for that template (layer).

Snapping is now enabled by default and has been broadened from being within an edit session only to being available across ArcMap. To this end, all the settings you need to work with snapping are located on the new Snapping toolbar, including turning on and off snapping types (edge, vertex, endpoint, and so on) and customizing the appearance of the cursor and SnapTips.

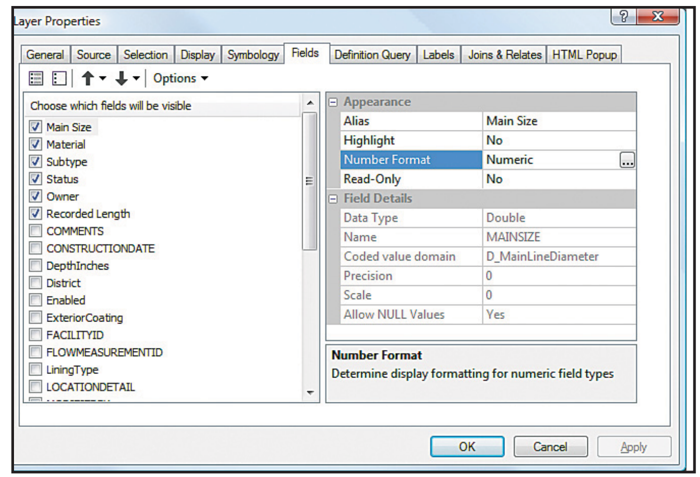
The Fields tab on the Layer Properties dialog box has been redesigned for 9.4, making it easier to reorder fields, turn them on or off, sort them, and set other display and formatting properties. These properties will be used throughout ArcMap, including the editor's attributes dialog box, table windows, and the Identify dialog box.



Meeting the Challenge with GeoDesign



Integration of design tools with existing GIS functionality is important, but it's only the first step. Ultimately, our vision is to expand the utility of GIS to the point that it is a foundational design system. As humanity comes to grips with its overwhelming impact on the natural world, we are also gaining a much better appreciation for our inextricable link to nature. And with that, of course, comes an enormous responsibility—a responsibility made all the more gargantuan by the fact that we still have a long way to go toward fully understanding the dynamics of the various systems and developing a robust suite of comprehensive models and other tools to support these activities. As Neutra did with architecture in the 1950s, we need to advance a framework for design and planning that not just incorporates but also embraces technology; science; and, ultimately, nature in a system that helps us design and choose the best alternative futures.



Imagine if your initial design concept, scribbled on the back of a cocktail napkin, has the full power of GIS behind it: the sketch goes into the database, becoming a layer that can be compared to all the other layers in the database. The experience ESRI has gained while developing CAD integration tools, ArcSketch, and the new tools in ArcGIS 9.4 has led to an appreciation of the power that could be derived by associating drawing tools, symbology, data models, and process models into one integrated framework for doing GeoDesign. Having "back of the napkin" design sketches available for immediate analysis and feedback is one of ESRI's primary areas of research and development over the coming years, and our users will see the results of these efforts in upcoming releases.

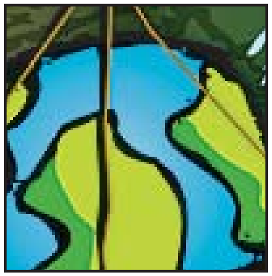
And the need for such tools has never been greater. We live in an ever more complex world, where our impact on the natural environment is massive and can no longer be ignored. People are starting to recognize the importance Neutra placed on the inseparable relationship between humans and nature and to realize McHarg's vision of design with nature, and they want to act.

"There is now a growing interest in combining design functionality with the broader geographical context that geospatial tools offer in order to engage more deeply in land-use planning," notes Matt Ball, editor at *V1 Magazine.* A GeoDesign framework will provide a robust set of tools for design professionals and finally meet the challenge of Ian McHarg, letting us truly design with nature.

(Reprinted from the Summer 2009 issue of *ArcNews* magazine)

Implementing Geographic Information Technologies Ethically

By Harlan J. Onsrud



As the globalization of geospatial information resources and services accelerates, it becomes far more challenging to protect personal information privacy; pursue traditional business or agency revenue generation models; protect property rights in spatial data products and services; ensure access to government data, records, and services; and provide security for our information systems. The traditional means of exerting control are often ill-suited to dealing with rapidly morphing technological and social conditions.

In this article, I explore some of the alternatives for envisioning relations among parties. In selecting possible control mechanisms, I argue that morally defensible geospatial technology designs and information system implementations are far more likely to survive and thrive in the long term, both within the marketplace and within and across democratic societies, than those that use other controls as their only touchstones in guiding relations. Several examples are cited. I argue further that the social and economic ramifications of technology developments and implementations need to be reflected upon up front in order to drive designs and implementations toward results that support laudable moral values, not as an afterthought by business managers, agency personnel, or code writers. After millions of lines of code have been written or substantial money has been spent on a system build, it is often too late or extremely burdensome to adjust. Consumers and citizens don't need to be sold on morally defensible designs and implementations. We all want them. Striving hard to understand and serve what consumers and citizens actually want will result in the highest payoff for businesses, government agencies, and society in general.

Societal Controls

When problems arise in our rapidly changing technological world, we tend to look to the law for solutions because its traditional functions have included settling disputes, maintaining order, providing a framework within which the common expectations of daily life can be met (buying groceries, driving, or using banking services), securing efficiency and balance in the functioning of government, protecting each of us from excessive or unfair government and private power, and ensuring that all members of society have an opportunity to enjoy the minimum decencies of life. The roles of the law are myriad, and we naturally look to the legal system for guidance. Yet, resorting to the law is not the first or best mechanism for defining our relationships with others.

The preferred priority of societal controls has often been listed in the legal literature as the marketplace, private arrangements, then the law. In this priority listing, price is viewed as a much better regulator of quality than laws, and support of the free will of parties, such as through agreements, is far more beneficial than having the law define what their relationships should be. In the context of the marketplace and private arrangements, the law serves a primarily supporting role in ensuring open competition and the enforcement of valid contracts. Looking to the law to define personal or resolve disputed relationships should be seen as a last resort.

For resources, such as geospatial products, that can be conveyed through cyberspace, the inherent characteristics of data and information make enforcement of controls particularly problematic. The theory is that the "invisible hand" of everybody pursuing individual economic interests drives greater efficiency and lower prices throughout the market. However, for this invisible hand to function effectively, goods in the market should have the characteristics of being rivalrous (e.g., my consumption of an apple adversely affects your consumption of the same good) and excludable (e.g., I need to be able to bar your use of the good for free), and the market must be transparent.

There are at least three major reasons provided in the literature as to why markets fail: public goods, externalities, and economies of scale.

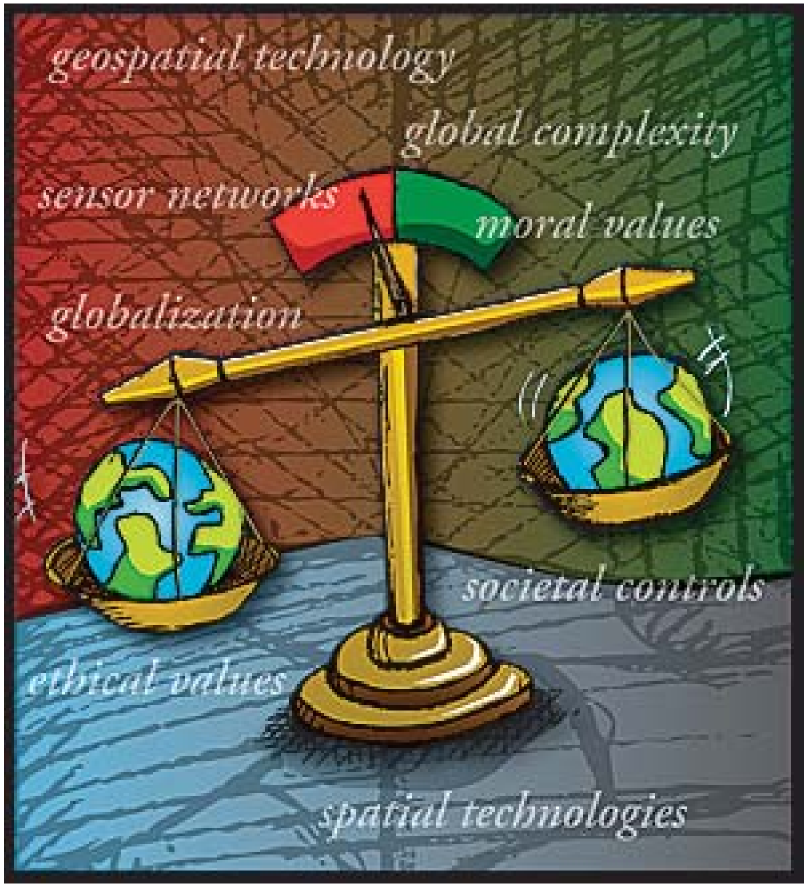


Illustration by Steve Pablo, ESRI.

The first of these failure concepts is perhaps the most critical for participants in geospatial product exchanges to understand. Public goods are not something defined as being supplied by the public but rather are goods that are nonrivalrous and nonexcludable. Information products and services are strongly nonrivalrous in that they may be consumed but not depleted. After digital geographic data, information, or products are given away or sold, the owner still possesses them. It is also very difficult to exclude "free riders" from gaining access to digital products once they have been distributed. As such, many of our geographic information products contain the opposite characteristics of those suited to an ideal Adam Smith market.

There is not much we in the geospatial industry can do about the nonrivalrous nature of our information goods. To date, the information industry in general has used two major mechanisms in attempts to convert inherently nonexcludable information goods to excludable goods.

The first is by action of law. In most nations, copyright and other intellectual property laws have been legislated that provide sanctions should copyrighted works be copied without permission. As we know from the widespread free rider sharing of music and movie files across the Web, enforcement through the laws of the world's nations has not been very effective to date in converting such nonexcludable goods to excludable goods across the globe.

The second approach is to use technology to prevent unauthorized persons from using one's information products, such as through digital rights management tools. To date, however, those using such systems have often lost in global market competition when competing with products that have taken an open approach to intellectual property protection and have allowed users to play and experiment with information products before buying them, when competing with products that are given away for free in order to build a market for related services, or when competitors are using an alternative economic model than one relying on intellectual property rights to create excludability.

A more useful framework for exploring controls that are and may be imposed among parties in both real space and cyberspace is the framework of law, norms, market, and architecture (Lessig—*Code and Other Laws of Cyberspace*). As we all know, laws are rules imposed by government, and sanctions are typically imposed after a breach occurs. Norms are standards of behavior, often within a specific community, and enforcement comes not from force of law but through violators being branded as antisocial or abnormal and stigmatized by the community. The market regulates through price and does so up front rather than after the fact. Finally, architecture constrains our behavior physically (e.g., I can't take your apples if they are locked in a room). Enforcement through architecture is immediate and does not require an intermediary, such as arrest of a lawbreaker or chastisement of a community member. The architecture of cyberspace is embedded in software code (i.e., I can't gain access unless I provide a user name and password).

Lessig argues that all four categories of constraints are in continuous operation whether in physical space or cyberspace. They influence each other, and all should be explored in the context of their combined effects when looking for solutions in promoting good behavior and constraining bad behavior in cyberspace. When considering specific behaviors, one or more constraints may have far greater utility than the others. By example, architecture (the code of spam filters) has been far more effective to date than law in dealing with spam.

While the above frameworks for exploring controls over activities in digital space are all useful, the critique has been made, with which I agree, that the ultimate regulator in setting the boundaries for activities and policies in cyberspace should be morality (Spinello—*Cyberethics: Morality and Law in Cyberspace*).

Spinello supports this position with the primary arguments that ethical values are more objective and universal, have greater enduring value, and therefore should be the basis for guiding and directing the ways in which computer code, laws, the market, social norms, and any other controls are used to shape behavior.

I suggest further pragmatic reasons for supporting moral values as the primary guide on which we should focus: ethical analysis processes are far more useful for geospatial specialists and organizations in guiding design and implementation actions. The guidance that ethical analysis provides is far more likely to result in higher economic and social benefits in the long run than that provided by merely staying on the right side of current law.

Globalization

Many of our geospatial products and services are now offered or accessible globally. The actions or approaches we take in one local community or nation to protect personal information privacy; pursue business or agency revenue generation models; protect property rights in spatial data products and services; ensure access to government data, records, and services; and provide security for our information systems can be significantly weakened or strengthened by the laws, information infrastructure, market products, and social norms supported elsewhere. A new geographic data product using a completely different model for generating revenues (e.g., Google Earth) may destroy many assumptions a company or agency might have about selling data products or services to users in its own community or jurisdiction. A digital product, such as software or a database a company may have spent millions to produce, may be stolen and distributed at the speed of light to people in other jurisdictions with little practical hope of recovering actual damages.

Law Versus Ethics

One problem with using the law in guiding our geospatial tool design and information system implementation decisions is this complexity caused by globalization. For example, the legal ownership status of scientific and technical information, including geographic data, is highly uncertain across the globe. Further, substantial differences in the law exist among jurisdictions. The typical geographic data user cannot know whether data found posted openly on the Web, extracted from a table in a print article, or automatically extracted from a networked database and included as a portion of the visual results from an online Web map service is protected by copyright or some other legal right. Even in science, the tradition of reproducing the data of others in one's work, then citing the source is no longer sufficient. Although many in society tend to ignore legal rules when they fail to meet our day-to-day expectations or they appear patently unjust as applied to our circumstances, the law in many jurisdictions now assumes that if the compiled digital data of others is used without their permission, it's done at the user's own legal peril. Just as one may not assume that any music file found openly available on the Web is free to copy legally without permission, the same holds true for most of our geographic digital products.

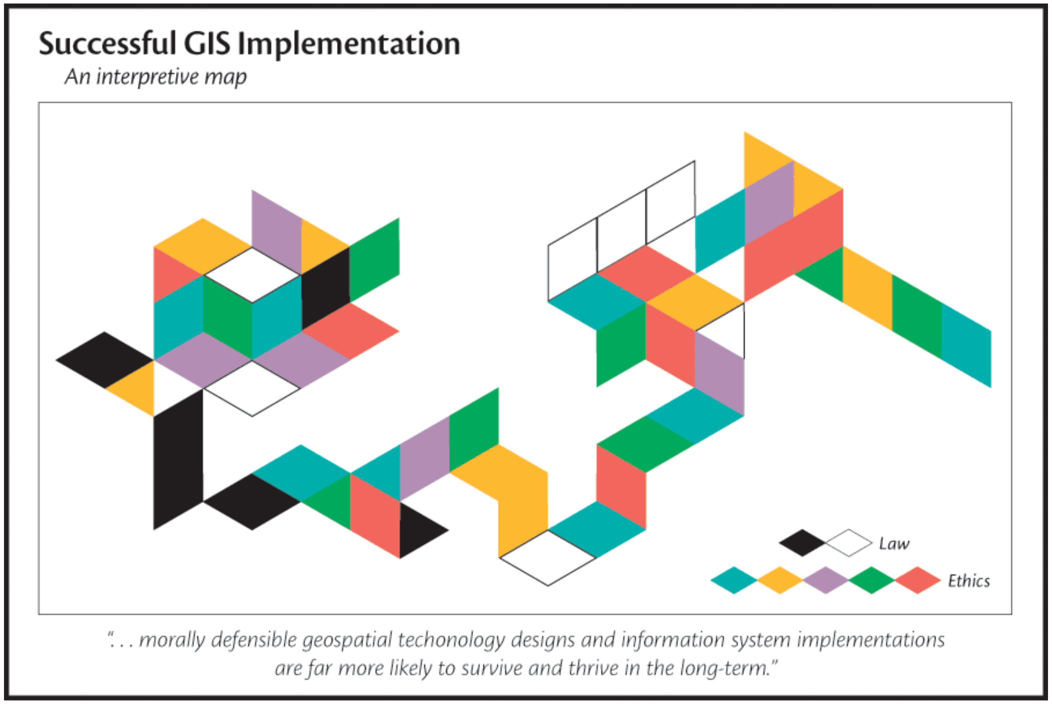


Illustration by Kyle Heinemann, ESRI.

In addition to its complexity, another problem with using law as a primary guide for our geospatial design and implementation decisions is that laws are passed on a majority-rules basis (or representative majority-rules basis), at least in democratic societies. Even in democratic societies, the concerns of minorities or disenfranchised parties may not be adequately protected if we seek to meet only the letter of the law in our designs and implementations.

A third problem with using the law as a primary guide is that legal rules tend to establish minimum standards of conduct and are applied on a basis where one rule applies to all. Minimally legal conduct often falls far short of morally defensible conduct. Examples abound of database implementations and software designs meeting the minimum legal standards for protecting the intellectual property or privacy rights of users but where the use of such data was found by most of the data subjects to be highly objectionable, even though technically legal.

In contrast, core ethical values are much more universal. The core values themselves tend not to change over time or with location. They are grounded in our common human nature across societies. Ethical values also supply us with laudable as opposed to minimum goals for the societal effects of our software designs and system implementations. Further, morally defensible designs and implementations tend to embed adaptability to individual human conditions and preferences. Thus, one-size-fits-all is not forced on users on a take-it-or-leave-it basis.

Simply following the law also typically provides little or no guidance in resolving a true ethical dilemma. Resolving a right-versus-wrong conflict does not create an ethical dilemma. We know what to do. Our duty is to choose the right action. An ethical dilemma occurs when one contemplated action is arguably right but will cause harm to others while the competing, alternative contemplated action or actions, including the alternative of doing nothing, are similarly right and proper but will also cause harm to others. Thus, we truly are conflicted about the right action to take.

Core Ethical Values

The science of ethics helps us sort out which moral arguments have greater validity. The two primary traditions in philosophy are deontological (concerning duty and obligations) and teleological (concerning ends) theories. As a gross simplification, under deontological theories, intent is everything. As long as you intended to do good or at least not do bad, your action is morally defensible. Under teleological theories, intent or motive doesn't really matter as long as the final result is good. Thus, although the marketplace might be vile, greedy, and focused on maximizing self-interest, if everyone in society benefits by having a free and open marketplace, perhaps the open marketplace has greater moral strength than alternative economic systems.

Over time, we have seen thousands of scholarly articles subcategorizing and attempting to reconcile these ethics traditions. Thus far, no single universal theory has emerged to provide us with a single clear-cut guide for our actions, yet the primary lines of ethical thought have many areas of agreement.

In assessing the moral validity of a contemplated action, such as a system design or implementation approach, we could indeed assess the action in the light of the traditional lines of philosophical reasoning. However, a more straightforward and contemporary solution is to focus on intermediary principles comporting with the primary ethical theories. While several theoretical frameworks might be used, I'll choose to illustrate some later examples using the concept of principlism as advocated by Beauchamp and Childress (Beauchamp and Childress—*Principles of Biomedical Ethics*).

Under this approach, certain prima facie duties are always in effect. They include autonomy of the person, nonmaleficence, beneficence, and justice. When assessing a planned action, all these duties always apply.

Briefly, autonomy is the duty to support self-determination in defining, planning, and pursuing a good life; nonmaleficence is the duty to avoid harm to others; beneficence is the duty to advance the welfare of others when able to do so; and justice is the duty to treat all fairly and impartially. When the duties are in conflict or one duty cannot be achieved, it needs to be asked whether there are alternative actions that might satisfy them all. If not, one needs to analyze the alternative design or implementation actions to determine which alternative might best achieve the duty viewed as being most critical to honor in the specific instance and minimize the harmful effects of not fully supporting one or more other duties.

For the long-term efficacy of software designs and system implementations involving the general public or consumers, moral issue consciousness and knowledge of ethical analysis processes for assessing contemplated actions by business managers, agency personnel, and code writers are extremely important.

There are several guidelines offered by practical ethicists. Most of the good guidelines automatically incorporate consideration of controlling laws and relevant disciplinary codes of conduct. In a straightforward case, resorting to law or codes of conduct may provide an answer that the designer or implementer can live with and perhaps one need go no further. In the tough cases, however, a systematic and rational procedure for thoroughly evaluating the situation is recommended. One that I use with both practicing professionals and students is the process and list of checkpoints advocated by Rushworth Kidder (Rushworth Kidder—*How Good People Make Tough Choices: Resolving the Dilemmas of Ethical Living*). The length of this article precludes stepping through a thorough assessment of a typical geospatial ethical dilemma. Rather, we jump to some examples to illustrate how moral values may have greater efficacy than law and other controls in guiding us toward rational solutions.

The Example of Intellectual Property

The music industry initially used the law as its primary guide and control mechanism in regulating the behavior of music file sharers. It pursued a closed approach to intellectual property protection in that only those purchasing full albums as defined and packaged by the traditional record companies or those subscribing to specific music services would have a legal right to possess or listen at will to the offerings of their artists.

Digital rights management systems were invoked to impose up-front control by locking out those who had not first paid an entry fee. These models would be strictly enforced through the application of law. However, this industry-wide model was viewed as unjust and illogical by large numbers of both consumers and artists in the light of current and emerging technologies. Was this position of the recording industry morally defensible? What alternatives might better support autonomy of the person, nonmaleficence, beneficence, and justice?

The current model of iTunes and similar download services is one that appears to be far more morally defensible in meeting societal needs. Focusing on the moral values of justice and fairness, the current implementation of iTunes Plus comports much more with the long-established legal bargain made between copyright holders and society in that, once a copy of a work has been purchased, "fair use" of the work without further payment is supported uninhibited by digital rights management constraints. This includes the right of the purchaser of a copy to transfer that copy to a reasonable number of other mediums for personal use.

The copyright holder (e.g., artist, recording company) is protected by using technology not to lock out access but by using technology to make purchasers accountable. It does so by attaching personally identifiable information to purchased files so that those who blatantly abuse the law by distributing their purchased copy to millions of others can be identified. ITunes and similar music sites support autonomy of the individual and beneficence by allowing artists to publicly publish their works in the manner in which they desire without controls imposed and fees extracted by intermediaries. Further, consumers have the ability to purchase individual tracks as opposed to collections packaged as albums. In terms of nonmaleficence, the harms of the economic, technological, and legal model pursued appear to be imposed primarily on competitors, and such harms, assuming a competitive marketplace, are typically viewed as a societal benefit by bringing down costs to make goods available to larger segments of society.

While Steve Jobs and other executives at Apple probably were not thinking explicitly of moral values in developing a workable solution for delivering music to consumers, their results remain an example where following a morally defensible path, as opposed to a legal rights advocacy path, has achieved far greater positive relations with consumers and profits for businesses. How might suppliers of geographic data and services similarly supply location-based data and services using approaches that are morally defensible while better achieving business and government objectives?

Ethics-Driven Implementations of Geographic Information Systems and Spatial Data Infrastructure: An Illustrative Intellectual Property Challenge

For at least the past quarter century, the debate has continued as to whether, under what circumstances, and to what extent property restrictions should be imposed on citizens and businesses in the use of geographic data that was gathered by domestic government agencies to meet government mandates and funded through general tax revenues. Similar debates surround the issue of whether data gathered for science through taxpayer-funded research grants should be made available to other scientists, businesses, and government agencies with no intellectual property restrictions imposed on the data. Much experience in pursuing various approaches exists.

I encourage students to explore the various approaches that have been used for the distribution of scientific and technical data, then have them articulate the moral values supported or not supported by these various approaches. We then search for market, legal, architecture (computer code), and social norm solutions that might better meet each and all of the moral values while still meeting pragmatic business and government objectives.

Development of one such solution was initiated (but not completed) in a research project entitled the Commons of Geographic Data (geodatacommons.umaine.edu). This particular system was envisioned as supporting volunteer contributions from any sector. The moral value and pragmatic assessment process concluded that the contribution of geographic data by geospatial specialists and nonspecialists throughout the scientific, government, and commercial sectors, as well as by the general public, often highly benefits all contributors and users. Not all actors in all sectors will contribute, but many will. We believe that more in these communities would be willing to share their geographic data files if an architecture provided a simple mechanism for doing so, creators could reliably retain credit and recognition for their contributions, liability exposure would be minimized, and contributors would obtain substantial benefits (e.g., increased recognition, long-term archiving of their data, peer evaluation, and credibility).

To meet these operational requirements, the architecture proposed would provide

- Open Access License Generation—With a few clicks, in less than a minute, users could create ironclad open access license conditions for any of their contributed datasets and bind that licensing information to the data.
- Automated Metadata Generation—With a few clicks and typed responses, in less than 10 minutes, users who are not GIScience professionals would use a simple mechanism for creating standards-based metadata.
- File Provenance Tracking—The system would automatically convert any contributed file to several standard interchange formats and track reuse of each of these files through generations of digital copying, aggregation, and partial extraction, ensuring that the parent lineage is always traceable.
- Peer Review Recommender Systems—The system would enable users to not only access data through standard search mechanisms but also evaluate data for its suitability to meet their needs, as well as provide feedback to contributors.
- Long-Term Archiving—Files would be archived and backed up at interconnected, long-term, institutionally supported facilities (e.g., libraries and research centers) that would not depend on the contributor's continual maintenance.

Notice that the architecture proposed for the geospatial community has several parallels with the iTunes architecture discussed above and is morally defensible using some of the same arguments. It uses an open approach to intellectual property management by allowing the tracing of major abusers of license conditions but not hiding the geographic data. Because of the public goods aspects of the proposed architecture, unlike iTunes, the architecture is unlikely to be provided through the competitive marketplace. Public or philanthropic funding would likely be required to resolve the research challenges and then develop and support such an architecture.

Several economic studies have confirmed that less restrictive intellectual property regimes often have far greater benefits for democratic societies and the world in general than more restrictive systems (e.g., Maurer—*Across Two Worlds: Database Protection in the US and Europe*) or approaches in which government competes with private companies (e.g., Weiss—*Borders in Cyberspace: Conflicting Government Information Policies and Their Economic Impacts*). Hence, the architecture suggested above incorporates open access licensing. However, a similar architecture supporting a morally defensible commercial license environment for geographic data and services is also certainly possible (National Research Council—*Licensing Geographic Data and Services*). Notice that it is possible to develop these morally defensible solutions entirely through architecture without the need to change any national laws or impose any other new controls.

Ethics-Driven Design of Geospatial Technology Development: An Illustrative Location Privacy Challenge

The mobile technology industry, as well as the location privacy literature, assumes a future in which government and corporate interests will have access and control over detailed information on the location and movement of objects and physical assets identified with individuals. Individuals will be granted, through legislation, a one-size-fits-all level of personal information privacy protection regardless of individual preferences and the changing nature of those preferences as technology and society change. While recognizing the importance of baseline personal information privacy that should be provided to all individuals through operation of the legal system, what if, instead, the global mobile tracking industry was built on the assumption that universal core moral values would be supported to the greatest extent possible? How instead would the technology evolve, and what explicit capabilities might the technology provide?

In assessing pervasive tracking systems that would support core moral values, imagine development of a handheld universal personal communicator. This device serves as a voice phone; receives and sends text messages, still images, and video; responds to voice commands and can respond back by voice; allows users to make purchases on the fly; tracks their location and provides directions or business information when asked; notifies them when they are near something they desire to buy or someone they wish to meet; tracks and warns of traffic problems and congestion; allows them to locate and track multiple friends on the fly; and performs other similar location and communication functions. This device is no longer difficult to imagine in economically developed nations. The corporate sector currently assumes ownership of the records of the time, location, transactions, and use of such systems, constrained only by one-size-fits-all legislative provisions and cumbersome opt-out possibilities.

A challenge I have frequently presented to engineering students is to conceptually design a prototype user interface that demonstrates how individuals might be allowed greater autonomy in deciding how, when, and at what detail their locations and movements may be tracked and retained by others. The design should increase beneficial uses of this type of technology, promote growth of the industry, and promote public security while granting individuals much greater flexibility and ease in protecting their personal information privacy.

One suggested approach resulted in recommending an integrated technological and legal solution that focused on an efficient interface for changing user privacy preferences on the fly with selections enforced through a dynamic contract (Anuket Bhaduri—*User Controlled Privacy Protection in Location-Based Services,* Master's Thesis, University of Maine, 2003). The suggested interface allowed users to be notified of the location and personal information exposure needed to take advantage of wireless services and allowed the user to set preferences, such as controlling who might contact the device user and by what methods (e.g., voice, text, video), the precision of the position and the time of the location of the user that might be exposed to businesses and to various user-defined categories of acquaintances, and the detail of data and time limits for storage of data by the service provider. All these decisions would be under the control and at the option of each user rather than under the control of the service provider. This work demonstrated that a practical design alternative does exist that would support autonomy of the individual by giving consumers the power to readily control their own information exposure. This particular research did not pursue in depth the issue of providing incentives or benefits for industry if companies redirected their approaches in this direction.

Another approach addressed the protection of personal information privacy in pervasive radio-frequency identification (RFID) tag environments (Eva Hedefine—*Personal Privacy Protection within Ubiquitous RFID Environments,* Master's Thesis, University of Maine, 2006). The assumption in this work is that we are rapidly entering a world where RFID readers will be as pervasive as security cameras, and each of us is likely to be carrying numerous publicly readable passive tags on our clothes and in our wallets as we travel in order to gain the numerous business and social advantages that these tags will provide. Once again, the recommended solution involved an integrated technological and legal solution as the best means of imposing controls to ensure a morally defensible publicly deployed system. In this instance, however, the recommendation is that legislation should be passed to drive technology to achieve the desired results of protecting personal information privacy while simultaneously allowing appropriate surveillance for security purposes. The legislation recommended takes the constitutionally defensible approach of a "do-not-link-to-identity" centralized list with wireless technologies developed to allow users to override their identity protection on the fly in instances where they want to gain a service that requires identity verification. The code controls would be imposed primarily within the RFID networked communication architecture rather than in the handheld devices or active sensors carried by consumers. One conclusion of this research was that the public goods aspect of generally deployed privacy protection for the public would prevent an appropriate market solution. To achieve a morally defensible solution would require an appropriate legislative mandate from the government to drive the development of infrastructure technologies in the appropriate direction.

The point of the preceding examples is to illustrate that the technological solutions advocated are ethically, legally, and marketplace situated.

Conclusion

All of our individual information resources ultimately will be part of a globally connected communication and interchange network. It makes sense in this evolving technological reality to think of ourselves as global citizens in addition to citizens of our local communities, nations, and professions and members of our business or government organizations. Implementers of geographic information systems, geospatial technology code writers, and builders of geographic databases and spatial data infrastructure need to be responsible, prudent, and comprehensive in incorporating basic moral values into the geospatial infrastructure we help create. Not only is this the right thing to do, but geospatial technology designs and information system implementations that are morally defensible are also far more likely to be mutually supported internationally by governments and to survive and thrive in the long term within the global marketplace.

About the Author

Harlan J. Onsrud is professor of spatial information science and engineering at the University of Maine. His research focuses on the analysis of legal, ethical, and institutional issues affecting the creation and use of digital databases and the assessment of the social impacts of spatial technologies. He is a licensed engineer, land surveyor and attorney and currently chairs the Socioeconomic Data and Applications Center (SEDAC) User Working Group, a Distributed Active Archive Center (DAAC) in the Earth Observing System Data and Information System (EOSDIS) located at the Center for International Earth Science Information Network (CIESIN), Columbia University. He is editor of *Research and Theory in Advancing Spatial Data Infrastructure Concepts* (ESRI Press, June 2007).

(Reprinted from the Fall 2008 issue of *ArcNews* magazine)

GIScience for Human Rights

"Crossing Borders"

A column by Doug Richardson, Executive Director, Association of American Geographers

Nearly all geographers and GIS specialists are concerned about human rights and in their personal and professional lives seek meaningful ways to act on these concerns and values. For the past two years, the AAG has been working together with the American Association for the Advancement of Science (AAAS) to explore an array of issues, projects, and programs that engage GIScience, geography, and human rights.

This collaborative work has resulted in substantive developments in three areas of human rights activity that intersect geography and GIS:

1. The creation of a new Science and Human Rights Coalition, of which the AAG is a founding member and co-organizer
2. Cooperation around an AAAS project on Geospatial Technologies and Human Rights
3. The development of an AAG Geography and Human Rights Clearinghouse

I am pleased to report on progress to date on these new programs and invite the ideas, input, and participation of the ESRI user community as we move forward.

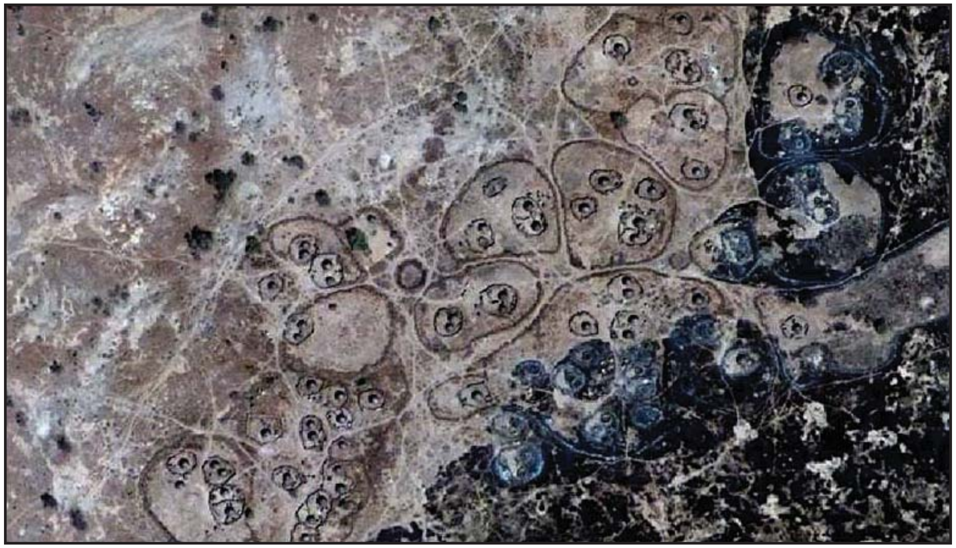
Science and Human Rights Coalition

For the past two years, the AAG has worked closely with AAAS and a team of other scientific and professional associations to help develop the conceptual and organizational framework for a proposed new Science and Human Rights Coalition, to be hosted by AAAS. The coalition is a network of individuals and scientific organizations that recognize a role for science and scientists in efforts to realize human rights. The working goals of the coalition are to promote human rights awareness and programs within scientific associations, professional societies, and science academies; facilitate collaborative partnerships between the scientific and human rights communities to address human rights challenges; create opportunities for scientific associations to explore and contribute their discipline-specific skills and knowledge to human rights; and expand the knowledge base of human rights organizations regarding scientific methods, tools, and technologies that can be applied in human rights work. Scientific associations that share the goals of the coalition are invited to participate as members. Individual scholars and scientists are encouraged to participate through their scientific organizations but may also be involved as affiliated members.

The village of Bir Kedouas, on the Chad side of the Chad/Sudan border, in October 2004. This QuickBird satellite image pictures the village before it suffered attack by the Janjawid.
(Copyright 2008 DigitalGlobe. Produced by AAAS.)

The formal launch of the new Science and Human Rights Coalition will occur January 14–16, 2009, in Washington, D.C. Speakers will include Mary Robinson, former United Nations High Commissioner for Human Rights and the former president of Ireland. The AAG is a founding member of the new coalition and is also playing an integral role in its launch. Further information about the new coalition and its formal launch is available at www.aag.org or shr.aaas.org/scisocs.

Geospatial Technologies and Human Rights Project



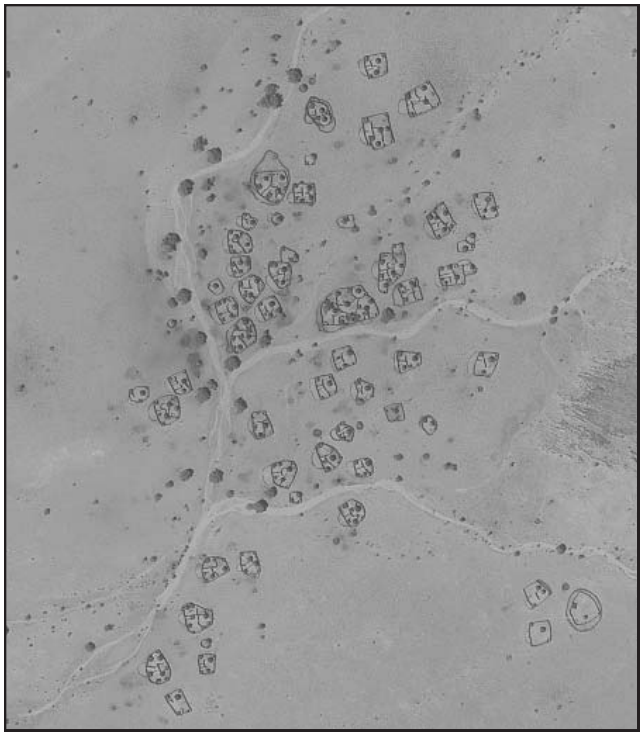
The village of Bir Kedouas following attacks by Janjawid fighters in January 2006. Analysis indicated that burning destroyed 89 homes, as well as crops and other structures.
(Copyright 2008 DigitalGlobe. Produced by AAAS.)

The AAG also supports and provides input to the AAAS Geospatial Technologies and Human Rights project, which is part of the AAAS Science and Human Rights Coalition. This project is funded by the MacArthur and Oak Foundations to develop applications, as well as human and information resources that improve the use of geospatial technologies and analysis by the nongovernmental organizational (NGO) human rights community. Working in partnership since 2006 with well-known groups, such as Amnesty International and Human Rights Watch, as well as numerous small, locally based organizations, the project has engaged in several efforts to bring high-resolution satellite imagery, GPS units, GIS, and geographic analysis and methods into wider use by human rights organizations. While such tools and analyses were occasionally used in the past, the project seeks to explore the potential for an integrated approach to monitoring, documenting, and preventing human rights abuses. Such a system would draw together numerous satellite imagery programs with the extensive network of on-the-ground NGOs and other human rights observers to fully document, as objectively and as quickly as possible, ongoing atrocities around the world so that interventions might occur. This project has also benefited from imagery analysis support and expertise from the U.S. Department of State's Office of the Geographer, headed by Lee Schwartz.

Specific efforts to date include documentation and active monitoring of attacks on civilians in Darfur, presented on the Eyes on Darfur Web site (www.eyesondarfur.org), as well as documentation efforts in Burma and the Ogaden region of Ethiopia. In such remote regions, governments often are able to commit atrocities against their citizens with near impunity, and satellite observations can often be the only method of authoritatively corroborating witness reporting for international NGO and governmental human rights organizations. To a more limited extent, such imagery can occasionally be effective as a proactive protection and warning mechanism, allowing innocent people to escape from harm's way or deterring attacks on monitored villages or sites. In addition, the project is currently engaged in efforts to support indigenous land rights in Guatemala, document adverse impacts of aerial defoliation in Colombia, and explore applications and needs of local human rights organizations in other regions.

AAG Geography and Human Rights Clearinghouse

The AAG and the AAAS also recently entered into an agreement, supported by funding from the MacArthur Foundation, to develop an inventory of geographic research and scholarship relating to human rights. This inventory and resultant detailed bibliography will form the foundation of a new AAG Geography and Human Rights Clearinghouse, which will be housed on the AAG Web site. We invite all AAG members and ESRI users, as well as others, to contribute to this clearinghouse. Among numerous applications and uses of this body of research, the AAG and AAAS particularly seek to identify research and project work that is substantive enough to be valuable as evidence or in support of expert testimony in international tribunals investigating human rights abuses. We would very much appreciate it if you could send citations of any geographic research or GIS project work that you believe would be useful for inclusion in this clearinghouse bibliography. Please e-mail research or project descriptions, bibliographic citations



Malam al Hosh is currently featured as a "village at risk" on the Eyes on Darfur Web site, and is now one of the villages being publicly monitored by Amnesty International in an attempt to deter threatened attacks.
(Copyright 2008 ImageSat International. Produced by AAAS.)

(preferably annotated with an abstract or brief summary of the work), and other relevant material to Megan Overbey (moverbey@aag.org) or Matthew Hamilton (mhamilton@aag.org) at the AAG.

Geographer and AAAS Human Rights Project director Lars Bromley noted that "Geographers and GIScientists obviously have critical and long-standing roles to play in human rights work. As such, AAAS is delighted to collaborate with the AAG in an effort to concisely identify relevant literature across a broad range of topics, which could inform future activities of interest to the human rights community." In addition to bibliographic, informational, and research resources, the AAG Clearinghouse will also provide links to other geography or GIS-related human rights programs, such as those of Amnesty International, the United Nations, and the U.S. Holocaust Memorial Museum's Genocide Prevention Mapping Initiative, among others.

More Information

Regular updates on these AAG and AAAS human rights programs will be available at www.aag.org and www.aaas.org.

(Reprinted from the Fall 2008 issue of *ArcNews* magazine)

Transport 2.0: Meeting Grand Challenges with GIScience

By Harvey J. Miller

Transportation is vital to contemporary economies and lifestyles. But in the 21st century, we are facing unprecedented challenges. Demand for transportation has increased dramatically over the past decades. Both transportation and communication technologies have made the world more mobile and interdependent. International trade relationships have altered the dynamics of manufacturing and consumption, heavily increasing the volume of freight traffic. Personal travel demand continues to rise at all geographic scales from local to global.

While in the past the strategy for managing transportation demand was simply to build more infrastructure, we are facing severe financial, environmental, and social constraints to expanding infrastructure. The convergence of ballooning demand and limited expansion has created enormous pressures on transportation systems. Our only choice is greater understanding of these complex systems and more informed decision making by transportation professionals and the public who use these systems.

This article describes the major challenges facing transportation in the 21st century. It also discusses the role of geographic information science (GIScience) and technology in helping create new ways of exploring and understanding transportation systems with the goal of improving decision making by both professionals and casual users. We also describe an effort by the Transportation Research Board (TRB) of the U.S. National Academies to identify the research and development required to achieve this vision over a decadal time frame.

Grand Challenges in Transportation

The TRB periodically identifies critical transportation issues based on their potential impact on the nation's economy and quality of life. Other critical issues, such as institutional challenges and finance, are not mentioned here. Although these are also critical, they are less directly relevant to GIS applications in transportation.

Infrastructure. The United States, along with many nations of the world, made massive investments in transportation infrastructure during the 20th century. However, this infrastructure is now old and used beyond its designed service life. This problem is not limited to highways; inland waterways and rail networks, as well as many sewer and water systems, have similar problems. The need to rehabilitate this infrastructure is occurring when higher demands are being placed on transportation systems and public investment is declining. How do we preserve and renovate saturated transportation systems without substantial increases in resources?

Congestion. Traffic congestion is a daily fact of life for many of the nation's and world's commuters. Estimates of the costs in money and gasoline lost by U.S. commuters every year range in the billions of dollars and gallons, respectively. In most cities, congestion is no longer limited to rush hours in the morning and evening; it has spread to many locations and hours of the clock. The burden of congestion is not limited to people; freight bottlenecks at ports and shipment delays at the local and regional levels place enormous costs on businesses and consumers. The growing need for efficient and responsive transportation to support the global economy and mobile lifestyles is occurring in an era when the ability to expand networks is increasingly limited. Can we maintain current or achieve improved levels of performance without substantial physical expansion?

Energy and the environment. The United States, as well as a burgeoning number of countries in the world, has an overwhelming reliance on the most energy-intensive transportation technologies, namely, automobiles and planes. The ability to continue reliance on petroleum-based transportation technologies is questionable in the short run but certainly impossible over the long run. Transportation systems have a direct and large environmental footprint, particularly with respect to air quality and contributions to global climate change. Over half the U.S. population lives in cities that do not meet federal clean air standards. Transportation also has an enormous indirect footprint through inducing other systems, such as cities, to manifest environmentally unsustainable forms, such as sprawl. Can we reduce the direct and indirect environmental footprints and achieve a sustainable transportation system despite increasing population and travel demands?

Illustration by Pamela Razor, ESRI.

Safety. The United States has been a world leader in transportation safety, and enormous progress has been made over the past century. Nevertheless, transportation continues to be the most dangerous activity experienced by a typical person. The United States is also falling behind other nations, such as the United Kingdom (UK) and the Netherlands, with respect to reducing fatalities and serious injuries caused by traffic accidents. While many of the improvements over the past century have made drivers safer, pedestrians and cyclists remain vulnerable. In the future, more people and vehicles within transportation systems with minimal physical expansion imply higher incidence of crashes with potential for injury and loss of life. Can we substantially reduce the number of transportation accidents without significantly reducing the efficiency and responsiveness of transportation systems?

Security and emergencies. September 11, 2001; the London and Madrid train bombings; and Hurricane Katrina illustrate the vulnerability of transportation systems to disruptions, both human made and natural. Transportation systems are popular terrorism targets since they concentrate large numbers of people into small spaces, increasing the likelihood of harm and enhancing psychological impact. Disrupting transportation systems can also strangle contemporary economies and lifestyles that depend on trade and mobility. Attempts to evacuate major U.S. cities, such as New Orleans and Houston, were ineffective. Can we prevent the improper and unauthorized use of transportation systems, and reduce our vulnerability to their disruption, without seriously restricting mobility or violating individual rights? Is it possible to evacuate a neighborhood, city, or region quickly and without additional injury or loss of life?

Equity. A transportation system that relies on personal vehicles creates significant disadvantages for many people, especially the poor, minorities, the elderly, the young, and others who cannot or choose not to drive. These problems will continue given current demographic and social trends. For example, most of the elderly population in the United States is aging in place, often in communities dominated by the automobile. Limited mobility can create isolation and social exclusion, establishing barriers to participating in society and enjoying its benefits. How do we meet the transportation needs of the growing numbers of diverse and vulnerable people?

Business as Usual?

Traditional design, planning, and investment methods, even those enhanced through GIS and related technologies, are unable to meet the grand challenges facing transportation systems. These methods view transportation problems as well defined and isolated. Transportation modes, such as road, rail, water, and air, cannot be viewed in isolation; transportation solutions are likely to be multimodal in nature. Transportation systems are tightly coupled with economic, social, and land-use systems: transportation networks affect, and are affected by, the broader systems in which they are embedded. There may be nontransportation solutions to problems traditionally viewed in that manner.

It is also increasingly clear that human systems, such as transportation and cities, are complex and difficult to manage, let alone control. We learn this lesson repeatedly as attempted changes in these systems lead to disproportionate, unintended outcomes. Rather, human systems must be nuanced: we can only set the framework for the evolution, not control its specific trajectory. This framework is often context specific. This is not defeatist; it simply suggests that we must be more clever and subtle than we have been in the past. We must achieve deeper understanding of these systems.

GIS for Transportation

GIS for Transportation (GIS-T) involves the application of GIScience and GIS for understanding transportation systems and solving problems associated with their planning, construction, operation, and maintenance. GIS-T has matured to the point that it is well positioned to provide useful tools and strategies to meet the challenges facing transportation systems in the 21st century. Contemporary developments that can inform efforts to meet transportation challenges include the following:

- Development and deployment of high-resolution environmental monitoring systems, such as satellite and airborne remote sensing
- Development and deployment of location-aware technologies and geosensor networks that allow fine-grained tracking of mobile objects
- Increasing ability of GIS to maintain and display spatiotemporal and moving objects data
- Improved science and tools for exploring and analyzing complex and massive spatiotemporal data
- Improved science and tools for simulating transportation, urban, and other human systems from the bottom up—at the level of the individual person, vehicle, or object
- Development and adoption of data standards and information infrastructures for integrating and interoperating data

While these scientific and technological developments clearly have great potential, the question remains—What do we do with all this new stuff? The challenges facing transportation systems are great and require new modes of thinking and analysis for their solution. Indeed, the transportation challenges offer a type of "moon shot": vital problems whose solutions will require long-term vision, as well as major scientific and technological advances.

Mirror Worlds

In his 1993 book *Mirror Worlds: Or the Day Software Puts the Universe in a Shoebox . . . How It Will Happen and What It Will Mean,* computer scientist David Gelernter describes a future where you look at your computer and see reality—the real-time status of an entire company, hospital, transportation system, or city.

Illustration by Fred Estrada, ESRI.

You start with a broad, geographic overview, perhaps a digital globe. You zoom in to your city. As you get closer, you see patterns—colors, shapes, and flows—draped on the city, representing the real-time status of its systems and infrastructure. Some patterns are static, some change shape, color, or intensity as the city changes in real time. As you zoom in closer, the representations automatically change to reflect greater detail. At the largest scale, you see vehicles—automobiles, planes, trains, ships—moving through a photorealistic, three-dimensional model of the city's buildings, roads, tracks, and waterways. But it is not quite real. Although they reflect real conditions, most of the vehicles are synthetic, except for some of direct interest to you (your car, your fleet, a delivery truck with a package for you). Also, many of these objects are augmented with text, sound, and imagery, reflecting some status that requires your attention or may capture your interest. You can even enter some of the buildings, for example, to attend a public hearing at city hall.

During your exploration, you meet other people who are visiting and participating in the mirror world. You also interact with virtual participants—software agents who act on your behalf, finding, digesting, and reporting information of interest to you, perhaps making some choices for you but alerting you when crucial decisions are required.

At any time you can navigate the scene and manipulate many of its objects; the flows and patterns change as they aggregate or disaggregate with the changing viewpoint. The displayed attributes may change as well, either automatically with the changing perspective or through your commands. You can also change the temporal scale: running the synthetic city backward or forward in time at varying rates, even exploring simulated futures. In addition to manipulating space and time, you can also explore for semantic similarity: find analogous states of the city or other cities that are similar to a real or imagined situation and see what happens.

Perhaps you are a busy person who needs to manage a hectic schedule. You use the mirror world to check real-time conditions of the transportation system and work with a virtual transportation concierge to determine the best schedule, travel, and mode choices (including cooperating with other users through carpooling or ride sharing) that allow you to accomplish the activities that comprise your day in a timely and efficient manner. But you are also a concerned citizen, and the mirror world allows you to participate in community decision making, say, tour a realistic depiction of the proposed light-rail line through your neighborhood, see the simulated future with and without the line, and search for other places and times with similar projects.

Or perhaps you are a project manager, dealing with the difficulties of designing and implementing the new light-rail line. You issue a call for public input. You post the current design as a 3D digital model, allowing the public to walk through and even "ride" the proposed system. You also post a simulation that shows the expected effects on the city in 10 years if this project is completed. The public can comment on all aspects of the project design and planning process.

Maybe you are a traffic manager, and you notice something strange: there is a local professional sports event, but traffic isn't streaming away from the stadium as expected. You check at the stadium and see that the game is going into overtime. You search for historical analogs and discover that overtime games during playoffs lead to an unusual amount of traffic on the Elm Street Bridge. Triggered by this query, a software agent informs you that the bridge on-ramp is undergoing unscheduled maintenance due to a water main break two days ago. You alert the local traffic police, as well as hospital emergency rooms, to let them know about the situation. The mirror world also propagates this to the general public, allowing them to change their schedules and trips in response to this event. An agent also sends a message to the local air quality monitoring board, suggesting that the unusual event may lead to an abnormal amount of vehicle emissions, perhaps requiring a voluntary "no-drive" day tomorrow.

A mirror world sounds like many of the Web-based tools we have available at present, such as digital maps; real-time snapshots of traffic or weather; applets; customizable Web pages based on your profile and browsing history; and virtual worlds, such as Second Life. Indeed, we have made a great deal of progress along the path described by Gelernter in 1993. But we are far from his vision. A mirror world goes beyond these current technologies to create a real-time, comprehensive, detailed, interactive, and discoverable portrayal of a complex real-world system. Unlike existing virtual worlds, the mirror world is not an alternative reality but a *reflection of reality* that is tightly coupled to the real world. It is also an *interpreted* world: the databases and data streams feeding the mirror world may be processed using knowledge discovery and visualization tools to aid legibility, provide decision support, and protect sensitive data. Some of the data may also be interpreted and presented by software or human agents.

Four key ingredients comprise a mirror world: One is a *live picture,* a comprehensive depiction of the state of a complex system right now, in real time. Another is a *deep picture,* an integrated representation that can be viewed at different levels of detail. *Agents* operate on our behalf to help deal with the complexity of this world. Finally, a mirror world must have a sense of *experience,* not simply an archival database one can query, but a way to search and retrieve relevant information from these previous states, including states that may be different but are good analogs for the current decision at hand. This should also include the ability to imagine alternative futures in what-if scenario modeling.

Your level of immersion in a mirror world can vary. It could be as basic as current social networking sites, such as Facebook, especially if you are accessing it through a mobile device, such as your phone. Or it could be a virtual but artificial world on your screen, such as Second Life. As virtual reality technologies improve, the mirror world could become a full sensory experience. Also, as augmented reality technologies improve, you will be able to see the mirror world superimposed on the real world through devices such as eyeglasses, windshields, and data projectors.

So What?

Sounds cool. But so what? David Gelernter suggests several profound, perhaps even transformative, benefits of mirror worlds.

Getting a grip. Contemporary organizations are fantastically complex. No one person can understand and participate in all the myriad decisions and problem solving required to run a hospital, transportation system, city, nation, or global community. The good news is that no one person needs to; we can share in this decision making, leaving some tasks to software and others to human experts. The mirror world can process the data you need, allow you to explore this information, and even alert you when a decision is required. In short, a mirror world helps you understand and deal with a complex reality by delegating mundane but overwhelming tasks and involving you when a real decision is required.

The new public square. A mirror world is a type of place where you can meet and interact with others, whether they are friends, neighbors, coworkers, fellow citizens, public officials, or business leaders. You can participate in activities ranging from a simple chat to a major policy change. Although this is possible in the real world, most people do not participate fully in community decision making: the real world is too big, complex, and costly to navigate. A mirror world reduces these barriers by creating a multiscale virtual world that is more easily discovered, navigated, and engaged.

The new conference room. A mirror world can also facilitate decision making that arises when diverse groups participate in a complex project, such as designing, building, and maintaining transportation infrastructure. A nascent example is the emerging field of building information modeling (BIM) for managing the construction life cycle through a three-dimensional, real-time, spatially referenced model of the building being constructed. BIM advocates claim better coordination, greater productivity, fewer errors, and savings in cost and time. Mirror worlds can scale this technology to large-scale transportation projects, including monitoring the infrastructure after installation to support management and maintenance. Combining this idea with the new public square, mirror worlds can allow public involvement at any stage of a facility's design, construction, use, and renovation.

Seeing the whole. One of the profound benefits of a mirror world is that it facilitates what Gerlernter calls *top-sight:* seeing the big picture. Top-sight is more than just a bird's-eye view or a synoptic summary. It also means seeing interconnections of parts, as well as the links between oneself and the whole. Top-sight is a form of insight; one can pursue it avidly but only achieve it gradually. It is a quality of great leaders and participants in well-functioning communities. The increasing complexity of the world makes top-sight more difficult. Although a mirror world cannot teach people to have top-sight, it can facilitate that view by managing the complexity that inhibits this holistic perspective.

Will mirror worlds solve the major problems facing transportation systems in the 21st century? Perhaps not. Some challenges may be too great, and others may require political will and leadership that may not exist. But a mirror world can certainly facilitate a better perspective on these problems, a view that is integrated, holistic, and multidimensional. It can also facilitate community mindfulness and public involvement. And it can help empower citizens and stakeholders to make better-informed transportation decisions at all spatial scales and time frames.

Transportation Worlds: What Do We Need?

How do we create this new instrument, the combined telescope, microscope, and time machine that is a transportation world? Much of the requisite science and many of the technologies currently exist, albeit in nascent form; these include GIS, geovisualization, agent-based technologies, virtual reality, and Web 2.0 tools. However, these technologies and the underlying science must achieve levels of maturity, sophistication, and interoperability that are beyond the current state of the art. Several major research and development trajectories are relevant.

Pervasive transportation information. New location-aware technologies and geosensor networks allow the collection of geospatial and temporal data at unprecedented scales and scope. It is unclear how best to deploy and support these data collection networks and how to deal with varying levels of data quality. There is also a need for new representation models that can accommodate the increasingly diverse data. More private citizens are volunteering geographic data through cell phones and other devices; how do we treat this data?

Transportation data must be integrated and shared across many applications and domains, often in real time. How do we efficiently integrate and archive this data, as well as make the data accessible to authorized individuals while preventing its misuse by unauthorized individuals?

Individuals will have unprecedented access to data and information about transportation systems. How will this change their behavior?

New knowledge for better transportation decisions. The unprecedented scope, spectrum, and detail of geospatial data collection technologies present a major challenge with respect to making sense of this data. Required are new methods for exploring the data, confirming discovered information, and communicating this information to transportation professionals and the public at large for collaborative decision making about transportation futures. We also need methods for automated detection of relevant information and unusual patterns for real-time response to tactical problems, including those arising when using transportation systems in one's daily life.

Imagined transportation worlds. Geospatial information and technologies can bring together the real and imagined worlds. How do we interoperate models and representations that are often designed for different purposes and at varying spatial and temporal scales? How do we judge the validity and utility of imagined worlds? How do we facilitate understanding of the scientific processes involved in simulating transportation futures to decision makers, stakeholders, and the public at large?

Geospatial infrastructures for transportation. The hardware and software issues involved in creating a real-time transportation world are enormous and will require advancements in basic GIScience, including new spatial algorithms, spatial data structures and processing, cyberinfrastructures to support spatial and temporal information, geovisualization techniques, and user interfaces. These should be designed with transportation systems in mind but must interoperate with methods and technologies in broader mirror worlds.

Also required are new processes to plan, budget, maintain, and upgrade geospatial technologies within public- and private-sector organizations. These infrastructures will require enterprise-wide investments and cannot be budgeted and built piecemeal.

Educating the transportation professional. New science, technologies, and data will place unprecedented demands on the education of the transportation student, as well as the continuing education and training of the transportation professional. Students will require foundations in transportation science, as well as the science underlying new geospatial technologies and data. It will be challenging to fit these demands within two- or four-year higher education programs, particularly those with strict accreditation requirements. There will also be a need to continue education and training throughout the career of a transportation professional as the technologies and software evolve in response to continuing advances in computer science, GIScience, and transportation science.

How Do We Get There? A Research Road Map

The Transportation Research Board Committee on Geographic Information Science and Applications (ABJ60) is involved in a multiyear effort to identify the research needed over a 10–20 year time frame for developing new geospatial science and technologies to meet the grand challenges facing transportation systems in the 21st century. The article you are reading is a product of this effort, and it involved many individuals (several are listed in the acknowledgments).

These efforts will continue through 2010 and beyond. We are developing a research road map that will identify the research trajectories and major milestones required to create the advanced geospatial environment for transportation described in this article.

We invite you to get involved. We need input from a diverse range of individuals concerned with transportation, either professionally or casually. Visit our Web site at abj60.org.

Notes

For discussion of critical issues in transportation, including some not mentioned in this article, see TRB Executive Committee (2006), *Critical Issues in Transportation,* Transportation Research Board, U.S. National Academies, Washington, D.C., available at trb.org.

Acknowledgments

The goal of the ABJ60 committee is to advance GIScience, technology, and applications in the field of transportation through research in communications and visualization; spatial data; systems integration, organization, and spatial analysis; and modeling. The committee also conducts outreach through TRB to communicate the effective use of GIS to the transportation community.

Many members and friends of the committee are involved in the strategic research vision described in this article as focus group leaders or participants; they are listed at the committee Web site, abj60.org. Special thanks to Reginald Souleyrette (committee cochair), Val Noronha (chair, research subcommittee), Cesar Quiroga (secretary), and Tom Palmerlee (TRB officer). An extra thanks to Roger Petzold (Federal Highway Administration) for supporting this effort.

About the Author

Harvey J. Miller is professor and chair of the Department of Geography at the University of Utah in Salt Lake City, Utah. His research and teaching interests include the application of geographic information science, spatial analysis, and geocomputational techniques for understanding how transportation and communication technologies shape individual lives and urban morphology. He has published more than 60 scientific papers on these topics. He is author (with Shih-Lung Shaw) of *Geographic Information Systems for Transportation: Principles and Applications* (Oxford University Press) and editor (with Jiawei Han) of *Geographic Data Mining and Knowledge Discovery,* second edition (Taylor and Francis). Miller serves on the editorial boards of several of the top scientific journals in GIScience, spatial analysis, and transportation and was the North American editor of the *International Journal of Geographical Information Science,* 2000–2004. He is currently cochairing the Committee on Geographic Information Science and Applications of the Transportation Research Board, U.S. National Academies.

(Reprinted from the Winter 2008/2009 issue of *ArcNews* magazine)

Geography Education and GIS Professional Development

"Crossing Borders"

A column by Doug Richardson, Executive Director, Association of American Geographers

In economically turbulent times, many students and college graduates will likely be wondering what options they have at their disposal. Is it time to jump into the job market, or is graduate school a better option? Indeed, many geography departments are hearing from students who are curious about advancing their career options and the value of an advanced degree in geographic information science (GIScience) for future employment. Fortunately, even in difficult times, GIS and GIScience students still enjoy growing opportunities to pursue geospatial work in business, government, and nonprofit organizations where spatial, environmental, and interdisciplinary skills are needed. Having strong academic preparation in geography and GIScience will only expand the career opportunities available to students, allowing graduates to enter the job market at a higher level and advance more rapidly through the ranks after being hired.

Within the past few years, a number of studies in the United States and the United Kingdom have addressed the issue of employability, a term describing the readiness of an individual to obtain and then maintain employment (Mistry, White, and Berardi 2006; Donert 2007; Solem, Cheung, and Schlemper 2008—see www.aag.org for full citations). All of these studies point to some important findings. First, hundreds of employer organizations across a broad swath of the business, government, and nonprofit (BGN) sectors seek individuals who are able to think spatially and use geographic technologies to collect, integrate, and analyze data on social and natural systems. And the good news for job seekers is that these same employers forecast an increasing demand for these abilities in the coming years.

A second important finding is that employers view geography education as an essential component of professional development in GIScience. This is because geography offers the conceptual frameworks, spatial science foundations, interdisciplinary perspectives, and spatial thinking skills underpinning effective use of GIS and related mapping technologies. In the experience of the employers surveyed and interviewed in this research, geographic learning through field studies, internships, and academic coursework enhances the work of geospatial professionals and helps ensure that the analytical power of geographic technologies is tapped productively.

Employers are also reporting broad and growing professional opportunities for GIScience graduates in areas as diverse as environmental management, transportation, public health, and international trade. Here, too, there are opportunities for GIS professionals to enhance their employability by taking advantage of new models of graduate education, such as professional master's degree programs, which integrate management training and internships with GIScience education. Among the many such programs are the new Professional Master's Program in geography at Temple University and similar master's degree and certificate programs in geographic information science offered by universities ranging from Arizona State University to Pennsylvania State University and dozens of others. The Guide to Geography Programs in the Americas provides a detailed overview of these educational opportunities (available at www.aag.org).

Many employers still report difficulties finding qualified graduates possessing strong preparation in geography and spatial analysis. In recent years, the AAG has undertaken research projects aimed at improving geography education for careers in BGN organizations (as well as in K–12 and higher education). One of the larger challenges identified in this work is the need to better align curricula with students' career aspirations and the needs of employer organizations. This is especially true in doctoral programs where Ph.D. students who once aspired primarily to careers in academia are now often attracted to equally rewarding and socially engaged careers in government, nonprofit organizations, and businesses. Departments in which the M.A./M.S. is the highest degree offered demonstrate clearer understanding of student goals and curricula that address BGN opportunities, but these programs still face challenges of implementation and helping students make transitions from traditional academic preparation.

The greater attention now given to BGN career preparation in geography graduate programs also holds promise for recruiting and retaining more women and minority students in the GIScience fields. This is because many of the students surveyed, including women and minority students, are especially interested in BGN careers, yet often feel that many purely technical graduate programs do not adequately provide them with the career advising and broader educational foundation they see as important to success in the GIS fields. But throughout the educational and career pipeline, students, parents, and teachers all need more information about the wide variety of GIScience career options available and the preparation required for success in these careers.

Given that context, the AAG has identified broad areas of critical data needs and actions for future work so that future graduates have a clearer sense of the opportunities available to them:

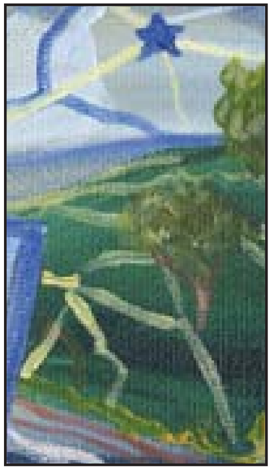
- Better data on the geographic and general skills that graduates employed in BGN positions use in their daily work
- Local, regional, and national estimates of employers' demand for geographic and geospatial skills in different types of BGN organizations
- Comparisons and assessments of undergraduate and graduate curricula in geography for preparation in BGN careers
- Continued development of disciplinary infrastructure to enhance graduate advising, career preparation, and transition support for early career geography and GIS professionals in BGN organizations, modeled after the success of recent National Science Foundation-funded programs, such as the Geography Faculty Development Alliance, and the AAG's Enhancing Departments and Graduate Education (EDGE) in Geography program

Geography graduate and undergraduate programs have undertaken a leading role nationally in providing the broad-based GIScience and GIS educational and research programs needed by students and employers across BGN sectors. Thanks to the hard work and goodwill of countless individuals in the geography, GIS, and GIScience communities, including notably those of our friends and colleagues within the ESRI education community, we are collectively developing the capacity for meeting the educational needs of our next generation of students and employers. For more information on educational programs available in geography, GIS, and GIScience, visit www.aag.org/education.

(Reprinted from the Winter 2008/2009 issue of *ArcNews* magazine)

Changing the Face of Geography: GIS and the IGU

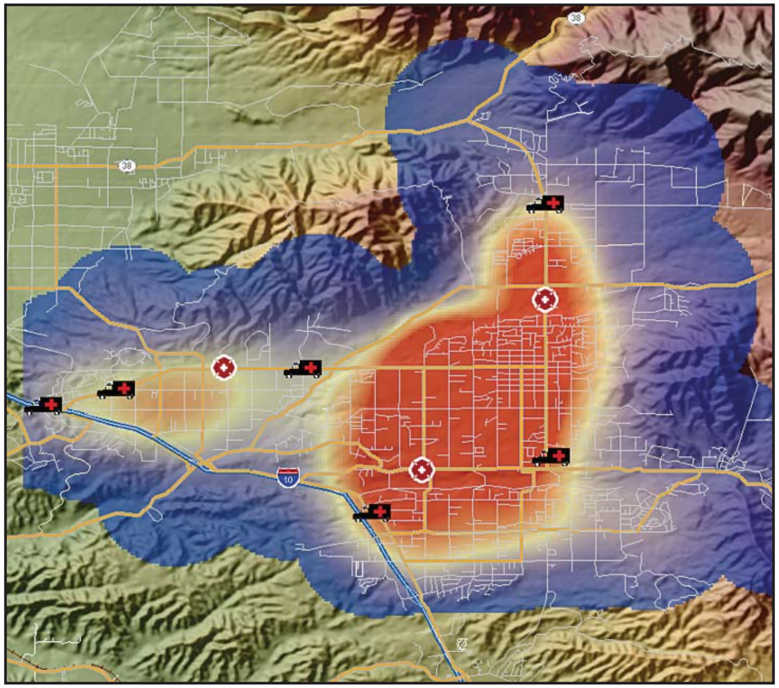
By Roger F. Tomlinson



Geographers—including those of the International Geographical Union (IGU)—have as their task the description and explanation of the living space of humans and the resulting spatial structure of society. The development of formal views of these concerns forms the basis for the modern science of geography. The extent and complexity of the world we live in make this task hard. The volumes of data that result from even cursory global investigation are a serious impediment to our understanding. Fifty years ago, it was not possible to handle any large set of the hard-copy maps and data that were being gathered, much less analyze them in any efficient way. The resulting inability—indeed the failure—to ask questions, let alone consider in depth the role of various interacting influences shaping the individual and societal factors, left us with a deep and generally unrecognized ignorance of space and time behavior.

The advent of computers as information processing tools and the development of GIS have measurably assisted geographers in their work. These new tools are being added to the discipline. Just as the advent of the telescope by Galileo increased the knowledge of the heavens and the concepts of space and the advent of the microscope revolutionized biology with its ability to add resolution and depth to inquiry, so the advent of the tools of GIS has impacted the discipline of geography. The quality of questions asked is rising, and the scope and use of spatial analysis are becoming more sophisticated. We are digging deeper into the spatial variables in considering factors that otherwise would not be explored. The trade-off between effort and inquiry is shifting in favor of inquiry. Workers are able to exchange their reasoning (decision models) very easily. This is contributing to the awareness of geography and the growing number of people becoming involved in the field. There is an increasing exchange of ideas and methods. As a result, the study of geography is changing significantly and beneficially and, in particular, expanding outside academic confines. Geography as a discipline is no longer encompassed by academic geography. It is not now principally reductionist and curiosity driven, with a goal to produce general laws (a long-established scientific method with great virtue). There is an urgent demand for the use of geographic science in government, relative to society, and to address the pressing issues facing the world. Geographers have major contributions to make to these issues.

There is, for example, broad agreement in the scientific community that the earth's climate is changing and that it is partly human induced. Very little is known, however, about the societal impacts of climate change, and there are very important geographic questions that need to be answered about changes in biogeochemical cycles, ecosystems, water resources, and resource utilization; continued atmospheric pollution; and the overall economic, political, and social implications. Geographers can contribute to the body of knowledge about climate change by synthesizing, analyzing, and modeling possible impacts.



The process of prepositioning ambulances for better service is one way in which GIS is used to examine spatial situations.

Similarly, with respect to human health and well-being, understanding of a population's health, the distribution of disease in an area, and the environment's effect on health and disease is central to human existence and a quintessentially geographic problem. There are also significant issues about the accessibility of health care and spatial distribution of health care providers.

Globalization is about interaction and integration among people, companies, and governments of different nations, a process driven by international trade and investment and aided by information technology. It has effects on the environment, culture, political systems, economic development and prosperity, and human physical well-being in societies around the world. Again, the analysis of these conditions has a strong spatial component.

Societal security is an essential goal of all governments and one that has become increasingly difficult to fulfill in recent years. In an area of asymmetric warfare, sociopolitical solutions have become ever more complex, and their impacts affect different communities and socioeconomic groups in different ways.

Sustainability entails meeting the needs of the present without compromising the ability of future generations to meet their own needs, and it still remains a problem, especially in light of accelerated environmental change and the current food crisis. Geographers have a great deal to contribute to understanding and solving this complex, multidimensional, essentially spatial problem.

Underpinning social diversity means understanding and generalizing the processes of spatial heterogeneity: defining characteristics of patterns and processes on the surface of the earth. Understanding these processes, which account for social diversity, difference, and inequality, is key to good governance.

The following are illustrations of some of the ways in which GIS is being used to examine spatial situations.

Climate—The Palmer Drought Severity Index is the basis for agricultural relief for farmers in major distress. Of particular interest is the analysis of drought on nuclear power plants. They require large volumes of water for cooling purposes, and sustained drought means that they have to be closed down, removing their supply of electricity in the states concerned.

Human Impact—The first human impact map of population density in two hemispheres is that of CO_2 emissions in the atmosphere, using real-time Jet Propulsion Laboratory satellite sensor information.

Population Density—Population density is provided as an element in the calculations of human impact and the human footprint.

Human Footprint—The human footprint aims to measure the extent of human interference on the earth's surface, using updated data on human population density, land transformation, human access, electrical power infrastructure, and settlements. This latest version was produced in 2008. The work was produced by the Humanitarian Information Unit of the Office of the Geographer and Global Issues (director, Dr. Lee Schwartz) of the Bureau of Intelligence and Research in the U.S. Department of State.

Human Health—Human health examines the interaction of spatial variables, including the U.S. Department of Agriculture's work with animal influence on human health; the outbreaks of avian flu in China by location; the tracing of the acute respiratory syndrome outbreak in China and Hong Kong to identify its origins; the National Cancer Institute's analysis of environmental effects on cancer incidents; and the relationship between smoking and birth weight in part of Ontario, Canada.

Avian Flu—Avian flu and bird migration routes illustrate the correlation between known outbreaks of avian flu and bird migration corridors to assist in the process of identifying the source and the diffusion of the disease. The same GIS application allows users to identify quarantine stations, flu shot clinics, and local public health departments.

Ambulance Location—The process of prepositioning ambulances for better service is examined. Contours of actual demand (call density) and the existing position of ambulances to meet that demand are calculated to optimize response travel times, affecting the efficiency of ambulance organization and survival rate in the area.

Flu Vaccine Distribution—Access to influenza vaccine distributions is compared to population distribution with access buffer zones of a one-mile and a two-mile radius around points of distribution of vaccines. Similar analysis is being used in preparation for avian flu epidemics.

AIDS—The progress on the U.S. President's Emergency Plan for AIDS Relief in sub-Saharan Africa is illustrated as a basis for policy change. Also included are results in Vietnam and

Guyana. Further analysis and understanding of the AIDS epidemic in Africa, particularly Kenya, Uganda, Tanzania, Zambia, and Malawi, come from analyzing patient data by gender showing the percentage of HIV-positive individuals in four categories (2–5 percent, 5–10 percent, 10–15 percent, and more than 15 percent of the population). Similarly, HIV prevalence among youth by first-order administrative divisions in the countries concerned is examined, again as a percentage of the general population and by gender. These studies underpin the effective delivery of AIDS relief in sub-Saharan Africa and the monitoring and analysis of program effectiveness.

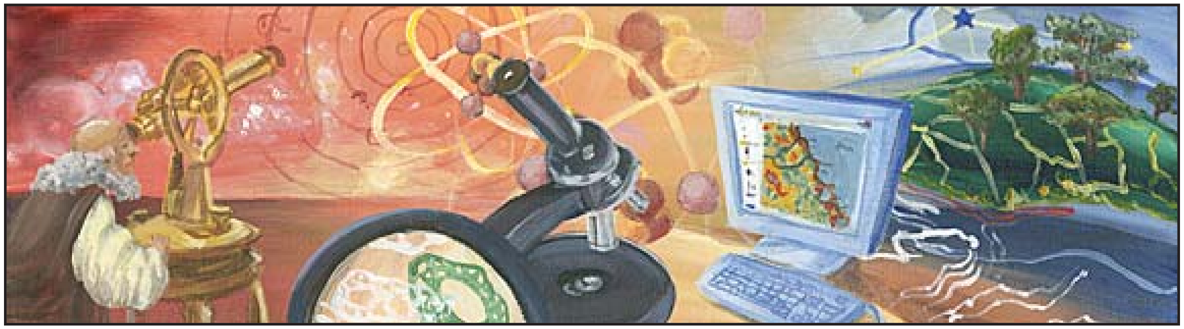


Illustration by Elizabeth Davies, ESRI.

The analysis of life and death in Africa is one with broad scope. It includes infant mortality rates, access to drinking water, overall AIDS infections, gross national income, and life expectancy by country. Bringing these variables together over a continent allows workers to better understand the measures necessary to improve the national condition.

Food Riots 2007–2008—The human condition of the world, particularly the food riots of 2007 and 2008, is tracked and illustrated. This is the first instance of a worldwide dimension.

Afghanistan Opium Cultivation—With Afghanistan supplying 80 percent of the world's heroin, this is a global issue. This map compares population density in Afghanistan with areas of poppy cultivation. The Taliban is operating extensively in the southern area of the country and has recently started operations in the northeast.

Habitat Destruction—Brazil graphically illustrates the extent of harvesting, which is systematically removing rain forest habitat.

Where to Plant a Billion Trees—The Green Belt Movement, spearheaded by Nobel Prize winner Wangari Maathai, is a political/environmental, and very successful, movement with the object of planting a billion trees in Africa. Peter Ndunda is the GIS coordinator for the project, actively working in East and West Africa to overlay soil types, climate, animal habitat, population density, and tribal lands to determine the most effective sites for planting. Without the GIS, trees would be planted in unfavorable sites. Their survival would be dubious, and popular political support would wither away.

Plant Hardiness Zone Migration—The Nature Conservancy at the University of Washington has calculated plant hardiness zones for 1960, 2008, and 2099. The movement north of the boreal forest and the ameliorating of temperatures in the Arctic islands are particularly noticeable. Implications for habitat can be measured and better appreciated.

Arctic Sea Ice—The Arctic sea ice conditions are put into perspective. National Aeronautics and Space Administration (NASA) data shows that Arctic perennial sea ice, which normally survives the summer melt season and remains year-round, shrank abruptly by 14 percent between 2004 and 2005. The loss of perennial ice in the east Arctic Ocean was even higher, nearing 50 percent during that time as some of the ice moved from the east Arctic to the west. The overall decrease in winter Arctic perennial sea ice totals 720,000 square kilometers (280,000 square miles)—an area the size of Texas. Perennial ice can be 3 or more meters (10 or more feet) thick. It was replaced by new, seasonal ice only about 0.3 to 2 meters (1 to 7 feet) thick that is more vulnerable to summer melt. The decrease in the perennial ice raises the possibility that Arctic sea ice will retreat to another record low extent this year. This follows a series of very low ice-cover years observed over the past four summers from active and passive microwave satellite data.

Travel History—By tracking the flights of one company over the course of a year and understanding environmental impact routes, the use of increasingly high-cost fuel and the distribution of future corporate locations/regional offices become understood.

Hydro Watershed—The hydro watershed of the Neuse River in North Carolina is a sophisticated exercise in flood probability and control based on rainfall and evaporation over the course of a year.

Humanitarian Aid—For the purposes of humanitarian aid, the U.S. Agency for International Development (USAID) determines the location of individuals affected by cyclone activity in Bangladesh. This analysis was used as a basis for extensive aid being provided in the right locations.

Another example of humanitarian aid produced by the Office of Foreign Disaster Assistance in USAID concerns the Greek wildfires of 2007. The principal map used by the project is the result of daily identification of five boundaries. In particular, the analysis concentrated on the degree of soil burn severity in the Kladios Basin, which allowed the focus of aid to be directed to those communities most affected by long-term damage and in the most desperate need of assistance.

Humanitarian aid provided by the U.S. Department of State in the Horn of Africa is concerned with the potential interaction of drought, locusts, flooding, and earthquakes, providing measures of the probability by hazard type to provide policy guidance for assistance in this area.

Humanitarian aid is the frequently minimized side of the U.S. Department of Defense, which uses mobile GIS in identifying needs and building the facilities for water supply in Afghanistan.

The Press Response—The press takes note of geography in action. There has been a series of newspaper headlines concerning GIS utilization in city operations, police department activities, real estate transactions, riverine studies, and so on.

Commercial Applications—Commercial store locations show the increasing use of geography in the business community, analyzing how specific retail outlets are located with respect to the driving distance (in miles) from their nearest competitors and the subsequent analysis of areas with access to more than one store to ensure that new store locations do not compete in the trade area of existing stores.

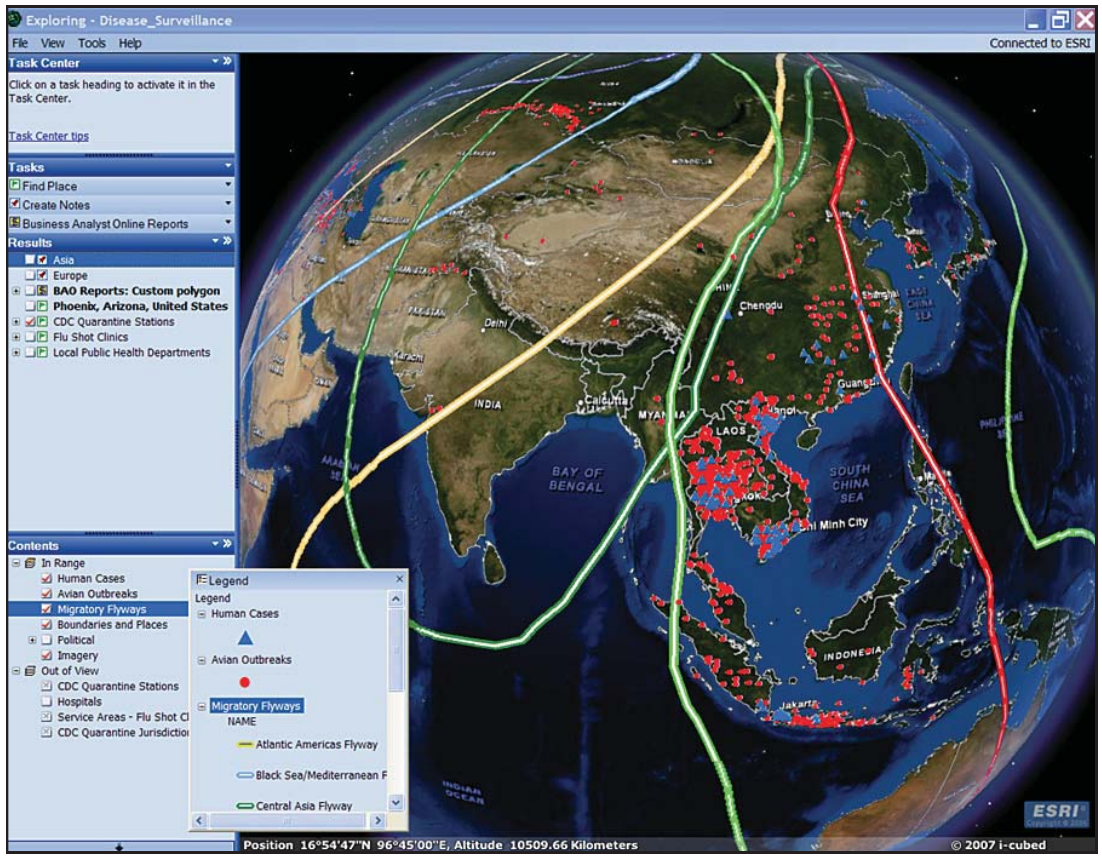
Summarizing the Spatial Situations

GIS combines the ability to manage stores of geographic data and perform spatial analysis and modeling to visualize output and disseminate results and methods.

It is not surprising that GIS and geographic analysis are being widely used. But the diffusion of geographic analysis methodology throughout the real world is quite remarkable. Based on licensing records, there are few countries or government departments in the world that are not using GIS. At least 5 million people in more than 300,000 institutions in more than 150 countries are using geographic methods in their work daily. And the largest campuses investigating geographic analysis are not in academia but in the private sector (e.g., ESRI has more than

2,700 U.S. employees, with 100 Ph.D. and 1,500 master's recipients, and adds numerous new graduates each year).

Using the assumption that every $1 million of investment in data and GIS requires at least one trained person for the investment to be used effectively, there is a shortfall of at least 3,000 trained people per year in North America alone, compared to the output from all universities and technical colleges in North America. Students are realizing that geography offers career opportunities and interesting jobs throughout the working world.



Avian flu and bird migration routes illustrate the correlation between known outbreaks of avian flu and bird migration corridors to assist in the process of identifying the source and the diffusion of the disease.

Interest in the discipline is growing everywhere. Academic geography may be splintering into quasi-named departments and subspecialties, but students who are trained in geographic analysis and can use the modern tools of GIS are in high demand. The growth of this interest is exemplified in the growth of the Association of American Geographers, which has increased significantly in size in the past decade and whose yearly conferences are attended by more people than ever (*see table below*). Similarly indicative is the reintroduction of geography at Harvard after an absence of 60 years in the new Center for Geographical Analysis. At the center's inauguration, the president of Harvard said, "Geographic information systems will let us change the nature of questions that are asked in a wide diversity of sciences and humanities."

Association of American Geographers Growth in Membership	
1998	6,910
1999	6,527
2000	6,497
2001	6,731
2002	7,004
2003	8,475
2004	9,041
2005	9,478
2006	10,086
2007	10,346

Indeed, a wide variety of problems has already been illustrated and is being addressed, but many broad-based issues still demand the attention of geographers.

There is a geography of security and terrorism that is multifaceted and comparatively little researched and understood, in spite of the fact that it could contribute enormously to this pressing problem. There is great scope in this area for the development of critical theories to examine alternative geographies.

The extensive development of quantitative geography in the 1960s and 1970s addressing the problems of analyzing and modeling space needs to be integrated with the GIS capabilities of today and brought together to develop wider and more generally applicable models of geographic space and time, focusing on interactions and dynamics.

We still have no adequate models for major cities, much less for the world itself. I am convinced that we—or at the very least, our grandchildren—will have them, but there are many research questions that remain to be investigated on the way to creating Al Gore's "digital earth." There are questions that touch on many aspects of geography, including representation, efficiency of information management, appropriate scientific visualization of issues, applications, and policy implications. I have no doubt that GIS will be at the core of this progress and that the future will be rich and productive.

International Geographical Union (IGU)

The International Geographical Union's interest in GIS originated in the Commission on Remote Sensing under the chairmanship of Dieter Steiner (1964–1968). The transition from photointerpretation to the handling of satellite imagery in digital form heralded the renaming of the commission in 1968 as the Commission on Geographical Data Sensing and Processing. This commission stayed in existence for 12 years under my chairmanship in the critical early stages of GIS. It held the first international GIS conferences in the world, published the first texts, established international cooperation between workers in the field, established academic and industry research teams, undertook inventory and description of all GIS software under development, and carried out appraisal of in-house systems for government agencies.

To put this into perspective, in the 1950s and 1960s, the links between computers and maps were tenuous at best. Workers were separated internationally and intellectually. Communication varied from poor to nonexistent. Academics found that, in general, their departments did not actively support their efforts; academic journals were not greatly interested, and their publishing delays did not serve the needs of the rapidly developing field. The field was being moved forward by people in institutions with a need for the capabilities, mainly in government departments, and in the private sector by those who wished to provide goods and services to government.

These needs were perceived to be those of agencies that produced paper maps and needed to automate the cartographic process and agencies that needed to read and geographically analyze maps (and related statistical data) and required geographic information systems to provide information for decision-making purposes. These requirements led to the initially separate development of automatic cartography systems and geographic information systems.

Clearly, there was a need for increased communication in the field and for providing support for academic colleagues, as well as establishing an international base for research and publication and a forum for discussion and networking. The IGU did that.

The first international conference on GIS was held in Ottawa, Canada, in 1970. Under the auspices of the IGU and with the assistance of UNESCO (particularly the support and guidance of Dr. Konstantin Lange) and the government of Canada, an invitation was sent to everyone known to be active in the field. Forty people were contacted and attended the conference, and by the end of the week, the first book on geographic information systems was created. It was entitled *Environment Information Systems* to take advantage of government's renewed interest in environmental concerns at that time. The primary objectives were to establish communication between workers in the field and to publish. Participants at the first meeting undertook to write a further text on the state of development of the field entitled *Geographical Data Handling.* This was published with the assistance of the United States Geological Survey (USGS) in 1972. It was a two-volume, 1,300-page text that reviewed all known developments of geographic data sensing, spatial data processing, spatial data manipulation and analysis, spatial data display, current systems, and the economics of geographic data handling. These were the first key texts in the field and were affectionately known as the "yellow and green telephone directories." One thousand copies were printed. They were available free of charge at the Second IGU Conference held in Ottawa that year. Three hundred people attended. Official delegations from 8 countries and workers from 15 countries were present. For the next few years, with the aid of the government of Canada, the IGU published a yearly directory of the names and contact information of the original participants and a description of their work. This list was subsequently added to voluntarily by additional workers and was sent to everybody listed. The communication process had begun.

In 1975, the commission also formed a critique group and carried out case studies on five geographic information systems in North America—their successes and failures—with the support of UNESCO, which published the work as a text in its Natural Resource Research Series in 1975. The IGU was also invited to review the work of the USGS. This was a two-year study and produced a seminal report in 1976 that alerted the major agency that it was committed to the digital age but was woefully unprepared to undertake commitments that it had already made. Also, for the first time, the IGU provided significant input to the work of the Committee on Data for Science and Technology of the International Council of Scientific Unions.

In the late 1970s, the IGU undertook an inventory of all computer software for spatial data handling, funded by the Resource and Land Inventory Program and the Geography Program of the U.S. Department of the Interior and directed by the renowned Dr. Duane Marble. This work represented the most comprehensive review of software for spatial data handling undertaken to that date, describing more than 600 systems and software programs worldwide. The resulting three-volume reference text was published by USGS in 1980 and made available at no cost to scientists worldwide. The commission also held interdisciplinary meetings in 1977 and 1978 to examine the methodological problems inherent in the future storage of large amounts of spatial data. These were held in Ottawa and Toronto, Canada, and Buffalo, New York. The IGU also contributed to the NASA meeting on Landsat data and geographic information systems in 1977.

Under the leadership of Dieter Steiner, it provided a three-week workshop in Nigeria on remote-sensing methods for regional and national planning in July 1978, funded by the Canadian International Development Agency and UNESCO. The working materials for this workshop included a three-volume text on the recent applications of remote-sensing technology for use by the commission.

From 1980 to 1988, the work of the Commission on Geographical Data Sensing and Processing was led by Marble. The activity concentrated principally on specialist meetings addressing major scientific concerns in the development of GIS. In 1988, the commission was renamed the Commission on Geographic Information Systems under the chairmanship of professor Sachio Kubo from Japan.

In all, the IGU carried out supervision of $1.5 million in grants and contracts between 1968 and 1980. The communication foundation had been laid, academic geographers were increasingly receiving recognition for their work, regularly published journals were becoming available, and GIS conferences worldwide provided a necessary continuation of the work begun by the International Geographical Union. In short, the IGU was the organization that nourished the growth of GIS and let it be a coherent part of geography for the benefit of the discipline as a whole.

Acknowledgments

Generous contributions to this paper were made by Dr. David Maguire and Dr. Duane Marble. The author also wishes to thank John Calkins and Jay Loteria for graphic assistance.

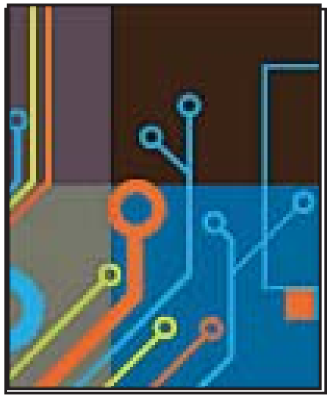
About the Author

Dr. Roger F. Tomlinson, CM, is president of Tomlinson Associates Ltd. Consulting Geographers, 17 Kippewa Drive, Ottawa, Ontario K1S 3G3 Canada. He was chairman of the International Geographical Union GIS Commission for 12 years, and he is known as the "father of GIS" as a result of his work in using computers to model land inventories for the Canadian government in the early 1960s. He is the author of many works, including *Thinking About GIS,* Third Edition, 2007, ESRI Press, Redlands, California.

(Reprinted from the Spring 2009 issue of *ArcNews* magazine)

Process Models and Next-Generation Geographic Information Technology

By Paul M. Torrens



Much of the inner workings of geographic information systems is organized around data models: computational structures (rasters and vectors are common variants) that determine how GIS stores, organizes, and displays various types of information for different purposes. Put simply, data models treat the world in terms of objects that represent entities and their related attributes. In GIS, there is usually no dedicated model of the processes that govern dynamics, adaptation, and evolution of a system. For many years, GIS has advanced the potential for unifying representations of entities and processes, and recently, the long-standing promise of consociating the two is beginning to be realized, enabling a burgeoning paradigm shift to a new style of GIS.

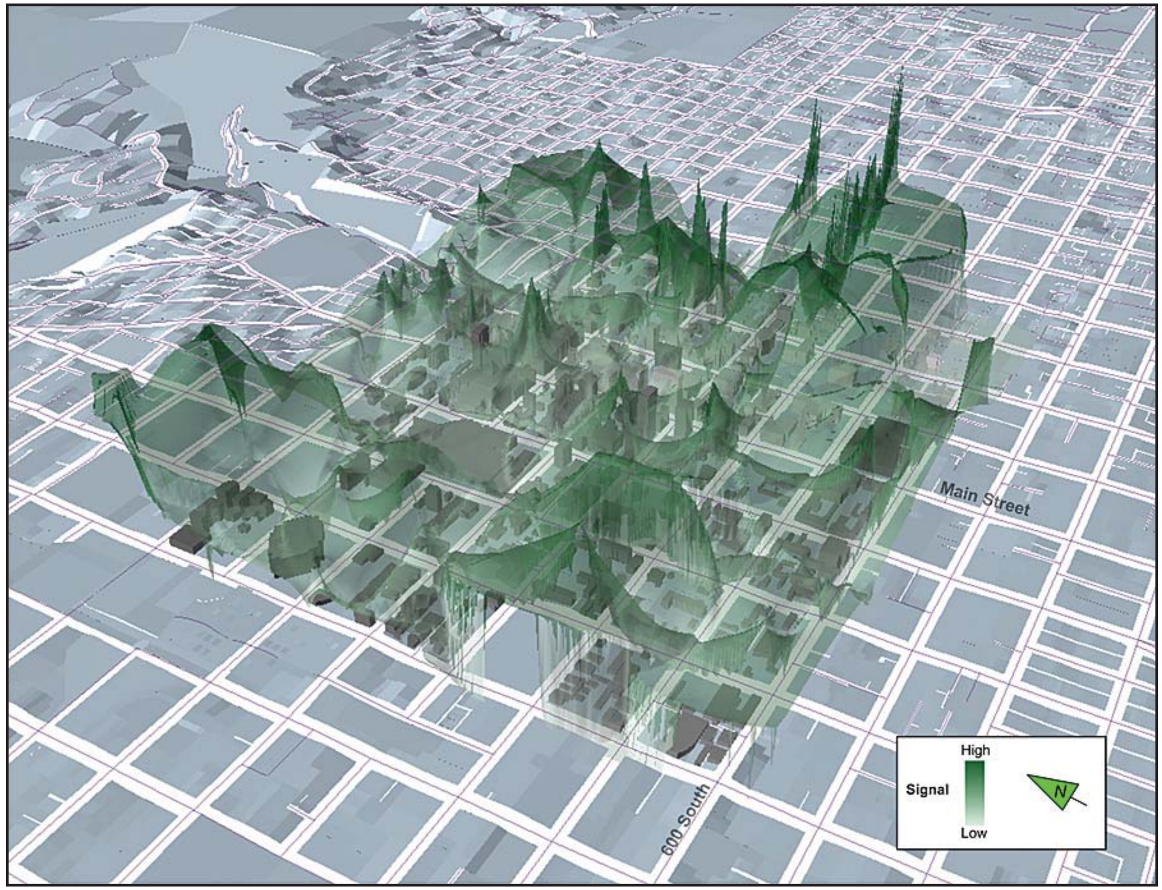
The next generation of geographic information systems will be driven by process models. These are usually composed of algorithms and heuristics that will act on users' requests for the GIS to perform some service for them, connect to digital networks to contextualize those requests, and interact seamlessly with other databases and processes to achieve users' goals. Alternatively, process models may be used as a synthetic representation of system parts to build artificial phenomena "in silico" that can be subjected to experimentation and what-if scenario building in ways that are not possible "on the ground." Geoprocessing has been featured with increasing priority in GIS for some time, and conventional GIS already relies on geoprocessing for spatial analysis and data manipulation.

Process models represent an evolution from these existing technologies, catalyzed by artificial intelligence that takes traditional GIS operations into the world of dynamic, proactive computing on a semantic Web of interconnected data and intelligent software agents. Imagine, for example, building a representation of the earth's boundary layer climate in GIS, but also being able to run dynamic weather patterns, storms, and hurricanes over that data, using climate models that sit in a supercomputing center on another continent. This article charts the development of process models in the geographic information sciences and discusses the technologies that have shaped them from the outside in. In addition, it explores their future potential in allying next-generation GIS to the semantic Web, virtual worlds, computer gaming, computational social science, business intelligence, cyberplaces, the emerging "Internet of Things," and newly discovered nanospaces.

Background

Much of the innovation for process models in the geographic sciences has come from within the geographic information technology community. Geoprocessing featured prominently in the early origins of online GIS, where server-based GIS delegated much of the work that a desktop client would perform to the background, hidden from the user. Interest in geoprocessing has resurfaced recently, largely because of increased enthusiasm for online cartography and expanding interest in schemes for appropriating, parsing, and reconstituting diverse data sources from around the Web into novel mashups that lean on application programming interfaces—interfaces to centralized code bases—that have origins in search engine technology.

Concurrently, many scholars in the geographic information science community have been developing innovative methods for fusing representations of space and time in GIS. This has seen the infusion of schemes from time geography into spatial database and data access structures to allow structured queries to be performed on data's temporal, as well as spatial, attributes. Time geography has also been used in geovisualization, as a method for representing temporal attributes of datasets spatially, thereby allowing them to be subjected to standard spatial analysis. Much of this work has been based around a move toward creating cyberinfrastructure for cross-disciplinary research teams, and significant advances have been made in developing technologies to fuse GIS with real-time data from the diverse array of interconnected sensors and broadcast devices that now permeate inventory systems, long-term scientific observatories, transportation infrastructure, and even our personal communication systems. In parallel, work in spatial simulation has edged ever closer toward a tight coupling with GIS, particularly in high-resolution modeling and geocomputation using cellular and agent-based automata as computational vehicles for animating objects through complex adaptive systems. Automata are, essentially, empty data structures capable of processing information and exchanging it with other automata. Simulation builders often turn to GIS routines in search of algorithms for handling the information exchange between automata, and over time, a natural affinity between the two has begun to develop into a mutually influential research field often referred to as geosimulation.



The cloud of Wi-Fi signals that envelops central Salt Lake City, Utah, generated by approximately 1,700 access points.

Much of the work in developing process models is finding its way into GIS from outside fields, however, and developments in information technology for the Web—and for handling geographic data on the Web—have been particularly influential. A massive growth in the volume and nature of data in which we find our lives and work enveloped has catalyzed a transition from a previous model of the Web to a newer-generation phase. The Web remains fundamentally the same in its architecture, but the number of applications and devices that contribute to it has swelled appreciably, and with this shift, a phase change has taken place, instantiating what is now commonly referred to as Web 2.0. The previous iteration of Web development was centered on static, subscription-based content aggregated by dominant portals such as AltaVista, AOL, Excite, HotBot, Infoseek, Lycos, and Yahoo! By comparison, much of the current generation model for the Web is characterized by user-generated content (blogs, Twitter tweets, photographs, points of interest, even maps) and flexible transfers between diverse data sources. Moreover, these varied data streams interface seamlessly over new interoperable database and browser technologies and are often delivered in custom-controlled formats directly to browsers or handheld devices via channels such as Really Simple Syndication (RSS). This takes place dynamically, updating in near real time as the ecology of the Web ebbs and flows.

Enveloping these developments has been a groundswell in the volume of geographic data fed to the Web. In many ways, Web 2.0 has been built on the back of the GeoWeb that has formed between growing volumes of location-enabled devices and data that either interface with the Web in standardized exchanges (uploading geotagged content to online data warehouses, for example) or rely on the Web for their functionality (as in the case of alternative positioning systems that triangulate their location based on wireless access points). The reduction in the cost of geographic positioning technologies led to the massive infusion of location-aware technology into cameras, phones, running shoes, and cars; atop bicycle handlebars; and in clothing, pets, handheld gaming devices, and asset-tracking devices on the products that we buy in supermarkets. Devices all over the world began to sense and communicate their absolute and relative positions, allowing, first, the devices to be location tagged; second, those tags to become a significant medium for organizing, browsing, searching, and retrieving data; and, third, their relative geography to become the semantic context that ascribes to those objects (and their users) information. Indeed, for many online activities, maps and GIS have become the main portal to the Web.

Semantic intelligence is driving the next evolution of the Web, characterized by the use of process models (usually referred to as software agents or Web services) as artificial intelligence that can reason about the meaning of data that courses through Internet and communication networks. A slew of ontological schemes—methods for classifying data and its relationships—provides the scaffolding that supports semantic reasoning online. Geography and location ontology is an important component of online semantics, allowing processes to not only know where something is in both network space and the tangible geography of the real world but also to reason about where it might have been, where it might go and why, whether that is usual or unusual behavior, what might travel with it, what might be left behind, what activities it might engage in along the way or when it reaches its destination, and what services might be suggested to facilitate these activities. Often, these may be location-based services that make use of the geographic position of a device, its user, or the local network of related devices, or they may make use of the network to deliver "action at a distance" to enrich a user's local experience, by connecting the user to friends across the world, for example.

Process models have also been developed in other information systems. Much of the potential for advancing geographic information technology stems from the ability of GIS to interface with other processes and related informatics through complementary process modeling schemes. The early precursors of this interoperability are already beginning to take shape through the fusion of GIS and building information models (BIMs). BIMs offer the ability of urban GIS to focus attention on a much finer resolution than ever, to the scale of buildings' structural parts and their mechanical systems. GIS allows BIMs to consider the role of the building in a larger urban, social, geological, and ecosystem context. When process models are added to the mix, the complementary functionality expands even farther. Consider, for example, the uses of a GIS that represents the building footprints of an entire city but can also connect to building information models to calculate the energy load of independent structures for hundreds of potential weather scenarios, or BIMs that can interact with an earthquake simulation to test building infrastructural response to subsurface deformation in the bedrock underneath, using cartography to visualize cascading envelopes of projected impact for potential aftershocks.

Virtual Worlds

Many advocates of the semantic Web envision a massive dynamic system of digitally networked objects and people, continuously casting "data shadows" with enough resolution and fidelity to constitute a virtual representation of the tangible world. These virtual worlds are already being built, and many people and companies choose to immerse themselves in online virtual worlds and massively multiplayer online role-playing gaming (MMORPG) environments for socializing, conducting business, organizing remotely, collaborating on research projects, traveling vicariously, and so on.

Here, process models are also driving advances in technology. Process models from computer gaming engines have been ported to virtual worlds, to populate them with automated digital assistants and synthetic people that behave and act realistically and can engage with users in the game world in much the same way that social interactions take place in the real world. Virtual worlds have been coupled with realistic, built and natural environment representations constructed using geometry familiar to GIS. The current generation of process models for MMORPG environments is relatively simple in its treatment of spatial behavior, but rapid advances are being made in infusing them with a range of behavioral geographies and spatial cognitive abilities that will enable more sophisticated spatial reasoning to be included in their routines.

Gaming is just one application of process models in virtual worlds. The actions and interactions of synthetic avatars representing real-world people can be traced with perfect accuracy in virtual worlds because they are digital by their very nature, and often, that data may be associated with the data shadows that users cast from their real-world telecommunications and transactional activities in the tangible world. Virtual worlds are seen by many as *terra novae* for new forms of retailing, marketing, research, and online collaboration in which avatar representations of real people mix with process models that study them, mimic missing components of their synthetic physical or social environments, mine data, perform calculations, and reason about their actions and interactions.

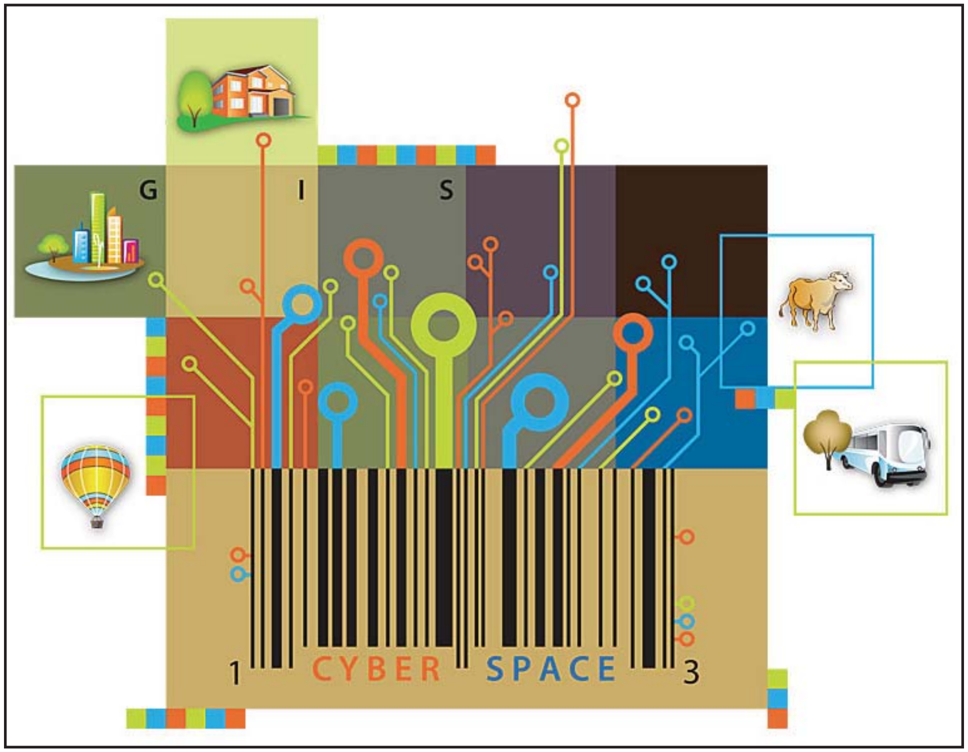


Illustration by Suzanne Davis, ESRI.

Code Space

Aspects of the semantic Web may seep into the real world, from cyberspace to "meatspace." In many ways, the distinction between the two has long ago blurred, and for many of us, our lives are already fully immersed in cyberplaces that couple computer bits and tangible bricks, and we find much of our activity steeped in flows of information that react to our actions and often shape what we do. Geographers have begun to document the emergence of what we might term a "code space," a burgeoning software geography that identifies us and authenticates our credentials to access particular spaces at particular times and regulates the sets of permissions that determine what we might do, and with whom, while we are there. Commercial vehicle traffic for interstate commerce, commuter transit systems, and airports are obvious examples of code space in operation in our everyday lives. Mail systems transitioned fully to coded space a long time ago: for parcel delivery services, almost every object and activity can be identified and traced as it progresses through the system, from collection to delivery on our doorstep. Other code spaces are rapidly moving to the foreground: patients, doctors, and supplies are being handled in a similar fashion in hospitals. Goods in supermarkets and shopping malls are interconnected through intricate webs of bar codes, radio-frequency identification (RFID) tags, and inventory management systems that reason about their position in a network of stores and even the supply geography of individual packets on a shelf. Similarly, transactions may be tagged at the point of sale and associated uniquely to customers using loyalty, debit, and credit cards that also link customers to their neighbors at home and similar demographic groupings in other cities, using sophisticated geodemographic analyses. The influence between location-aware technology and sociology is also beginning to reverse. Other code spaces facilitate the emergence of "smart mobs" or "flash mobs," social collectives organized and mediated by Internet and communications technologies: text messaging, instant messaging, and tweeting, for example, for the purposes of political organization; social networking; or, as is often the case, simple fun.

The Internet of Things

In technology circles, objects in a code space are referred to as "spimes," artifacts that are "aware" of their position in space and time and their position relative to other things; spimes also maintain a history of this location data. The term *spime* has arisen in discussions about the emergence of an Internet of Things, a secondary Internet that parallels the World Wide Web of networked computers and human users. The Internet of Things is composed of (often computationally simple) devices that are usually interconnected using wireless communications technologies and may be self-organizing in formation. While limited individually, these mesh networks adopt a collective processing power that is often greater than the sum of its parts when their independent process models are networked as large "swarms" of devices. Moreover, swarm networks tend to be very resilient to disruption, and their collective computational and communication power often grows as new devices are added to the swarm. Networks of early-stage spimes (proto-spimes) of this kind have already been developed using, for example, microelectromechanical systems (MEMS), which may be engineered as tiny devices that are capable of sensing changes in electrical current, light, chemistry, water vapor, and so on, in their immediate surroundings. When networked together in massive volumes, they can be used as large-geography sensor grids for earthquakes, hurricanes, and security, for example. Sensor readings can be conveyed in short hops between devices over large spaces, back to a human observer or information system for analysis. MEMS often contain a conventional operating system and storage medium and can thus also perform limited processing on the data that they collect, deciding, for example, to take a photograph if particular conditions are triggered, and geotagging that photograph with a GPS or based on triangulation with a base station.

Geodemographics and Related Business Intelligence

The science and practice of geodemographics are concerned with analyzing people, groups, and populations based on tightly coupling who they are with where they live. The *who* in this small formula can provide information about potential debtors', customers', or voters' likely economic profile, social status, or potential political affiliation on current issues, for example. The *where* part of the equation is tasked with identifying what part of a city, postal code, or neighborhood those people might reside in, for the purposes of allying them to their neighboring property markets, crime statistics, and retail landscapes, for example. Together, this allows populations and activities to be tagged with particular geodemographic labels or value platforms. These tags are used to guide a host of activities, from drawing polling samples to targeting mass mailing campaigns and siting roadside billboards. The dataware for geodemographics traditionally relied on mashing up socioeconomic data collected by census bureaus and other groups with market research and point-of-sale data gathered by businesses or conglomerates. Traditionally, the science has been relatively imprecise and plagued with problems of ecological fallacy in relying on assignment of group-level attributes to individual-level behavior. Because of early reliance on data from census organizations, which aggregate returns to arbitrary geographic zones, the spatial components of geodemographics have also suffered from problems of modifiable areal units (i.e., there are an almost infinite number of ways to delineate a geographic cluster). Data is often collected for single snapshots in time and is subject to serious problems of data decay; households, for example, may frequently move beyond or between lifestyles or trends, without adequate means in the geodemographic classification system to capture that transition longitudinally.

Process models could change geodemographics. When users browse the Web, their transactions and navigation patterns, the links they click, and even the amount of time that their mouse cursor hovers over a particular advertisement can be tracked and geocoded uniquely to their machine. Users' computers can be referenced to an address in the Internet protocol scheme, which can be associated to a tangible place in the real world using reverse geocoding. Along retail high streets and in shopping malls, customers now routinely yield a plethora of personal information in return for consumer loyalty cards, for example, or share their ZIP Codes and phone numbers at the point of sale, in addition to passively sharing their names when using credit or debit cards. By simply associating an e-mail address to this data, it is relatively straightforward, in many cases, to cross-reference one's activity in the tangible world with one's data shadow in cyberspace. Developments in related retail intelligence, business analytics, inferential statistics, and geocomputing have increased the level of sophistication with which data can be processed, analyzed, and mined for information. This allows the rapid assessment of emerging trends and geodemographic categories. Process models are even coded into the software at cash registers in some instances.

Much of this technology is allied to spimes and code spaces. Technologies based around RFID and RFID tagging, initially designed for automated stock taking in warehouses and stores, are now widely embedded in products, cards (and therefore wallets), and the environment with such pervasiveness that they enable widespread activity and interaction tracking, particularly within a closed environment such as a supermarket. Coupled to something like a customer loyalty card, these systems allow for real-time feeds of who is interacting (or not) with (not just buying, but handling, or even browsing) what products, where, when, with what frequency, and in what sequences. The huge volumes of data generated by such systems provide fertile training grounds for process models.

The increasing fusion of mobile telecommunication technologies with these systems opens up a new environment for coupling process models to mobile geodemographics. This is a novel development for two main reasons. First, it creates new avenues of inquiry and inference about people and transactions on the go (and associated questions and speculations regarding where they may have been, where they might be going, with whom, and to do what). Second, it allows geodemographic analysis to be refined to within-activity resolutions. This has already been put to use in the insurance industry, for example, to initiate pay-as-you-go vehicle coverage models, using GPS devices that report location information to insurance underwriters. Mobile phone providers have also experimented with business models based around location-based services and location-targeted advertising predicated on users' locations within the cell-phone grid, and groups have already begun to experiment with targeting billboard and radio advertising to individual cars based on similar schemes. New GIS schemes based around space-time process models and events are well positioned to interact with these technologies.

Nanosystems

When spimelike devices are built at very small geographies, capable of sensing and even manipulating objects at exceptionally fine scales, they become useful for nanoengineering. In recent years, there has been a massive fueling of interest in nanoscale science and development of motors, actuators, and manipulators at nanoscales. With these developments have come a veritable land grab and gold rush for scientific inquiry at hitherto relatively underexplored scales: within the earth, within the body, within objects, within anything to be found between 1 and 100 nanometers. Geographers missed out on the last bonanza at fine scales and were mostly absent from teams tasked with mapping the genome. The cartography required to visually map the genome is trivial and the processes that govern genomic patterns are completely alien to most geographers' skill sets, so their exclusion from these endeavors is understandable. The science and engineering surrounding nanotechnology differ from this situation, however, in that they are primarily concerned with spatiotemporal patterns and processes and the scaling of systems to new dimensions. These areas of inquiry are part of the geographer's craft and fall firmly within the domain of geographic information technologies. Process models with spatial sensing and semantic intelligence could play a vital role in future nanoscale exploration and engineering.

Computational Social Science

Geographic process models also offer tremendous benefits in supporting research and inquiry in the social sciences, where a new set of methods and models has been emerging under the banner of *computational social science.* Computational social science, in essence, is concerned with the use of computation—not just computers—to facilitate the assessment of ideas and development of theories for social science systems that have proved to be relatively impenetrable to academic inquiry by traditional means. Usually, the social systems are complex and nonlinear and evolve through convoluted feedback mechanisms that render them difficult or impossible to analyze using standard qualitative or quantitative analysis. Computational social scientists have, alternatively, borrowed ideas from computational biology to develop a suite of tools that will allow them to construct synthetic social systems within a computer, in silico, that can be manipulated, adapted, accelerated, or cast on diverging evolutionary paths in ways that would never be possible in the real world.

The success of these computational experiments relies on the ability of computational social science to generate realistic models of social processes, however, and much of the innovation in these fields has been contributed by geographers because of their skills in leveraging space and spatial thinking as a glue to bind diverse cross-disciplinary social science. Much of computational social science research involves simulation-building. To date, the artificial intelligence driving geography in these simulations has been rather simplistic, and development in process models offers a potential detour from this constraint. Moreover, computational social science models are often developed at the resolution of individual people and scaled to treat massive populations of connected "agents," with careful attention paid to the social mechanisms that determine their connections. This often requires that large amounts of data be managed and manipulated across scales, and it is no surprise that most model developers turn to GIS for these tasks. Connections between agent-based models and GIS have been mostly formulated as loose couplings in the past, but recent developments have seen functionality from geographic information science built directly into agent software architectures, with the result that agents begin to resemble geographic processors themselves, with realistic spatial cognition and thinking. These developments are potentially of great value in social science, both in providing new tools for advanced model building and in infusing spatial thinking into social science generally. At the same time, developments in agent-based computing have the potential to feed back into classic GIS as architectures for reasoning about and processing human environment data.

Prologue

This is a wonderful time to be working with or developing geographic information technologies, at the cusp of some very exciting future developments that will bring GIS farther into the mainstream of information technology and will infuse geography and spatial thinking into a host of applications. Of course, some potential sobering futures for these developments should be mentioned. As process models are embedded in larger information, technical, or even sociotechnical systems, issues of accuracy, error, and error propagation in GIS become even more significant. Ethical issues surrounding the use of fine-grained positional data also become more complex when allied with process models that reason about the significance or context of that data. Moreover, the reliability of process models as appropriate representations of phenomena or systems must come under greater scrutiny.

About the Author

Dr. Paul M. Torrens is an associate professor in the School of Geographical Sciences at Arizona State University and director of its Geosimulation Research Laboratory. His work earned him a Faculty Early Career Development Award from the U.S. National Science Foundation in 2007, and he was awarded the Presidential Early Career Award for Scientists and Engineers by President George W. Bush in 2008. The Presidential Early Career Award is the highest honor that the U.S. government bestows on young scientists; Torrens is the first geographer to receive the award.

(Reprinted from the Summer 2009 issue of *ArcNews* magazine)

Geographic Literacy in U.S. by 2025

"Geo Learning"

A column by Daniel C. Edelson, Vice President for Education, National Geographic Society

For more than a decade, the National Geographic Society and ESRI have worked together to advance the cause of geographic literacy in the United States.

This new *ArcNews* column represents the next step in that collaboration. We are reaching out to the ESRI user community, the largest organization of GIS professionals in the world, to engage you in this important campaign.

In this inaugural column, I will address the questions of what geographic literacy is and why GIS professionals have such an important role to play in our campaign to increase the rate of geographic literacy in the United States. In future "Geo Learning" columns, I will describe specific ways that you can get involved in this effort.

It's no secret that Americans know next to nothing about geography. The most recent National Geographic/Roper Poll (2006) found that half the 18–24-year-old Americans surveyed could not locate New York on a map of the United States, and nearly 6 in 10 could not locate Ohio.

One-third of the young adults in the survey gave the wrong answer when asked to name the continent where the Amazon rain forest is located. And, after being at war with Iraq for three years, 63 percent of young Americans could not identify Iraq on a map of the Middle East.

If you're like me, you find it hard to believe those statistics because they are so discouraging, but they are true. However, by paying too much attention to these statistics, we could easily teach American schoolchildren a lot of disconnected geographic facts about the world that distract us from what people really need.

Knowing geography facts does little good if you can't do something with those facts. People don't need to know geography, they need to be able to do geography. To me, doing geography is what geographic literacy is all about.

The problem facing American society right now is that most people don't even know what it means to do geography. So who does know what it means to do geography and understand why it is so important? You do.

GIS professionals know what it means to analyze and solve geospatial problems. GIS professionals routinely apply geographic analysis to complex situations, predict consequences, construct plans, and make decisions. Not only do GIS professionals know what it means to do geography, they also understand how valuable the ability to do geography is to them individually, to their employers, and to our society.

To me, GIS professionals represent the standard against which we should measure geographic literacy. I do not mean that every individual should have the level of expertise that GIS professionals have. That's neither appropriate nor realistic.

However, we should aspire to having all Americans be able to conduct basic geographic analysis in order to make sound personal, political, and professional decisions. This is not about technology, either; I'm not arguing that all Americans need to be able to use a GIS.

My point is about analysis. I believe that every American should understand how the attributes of a location and its relationship to other locations affect that location. Every adult should understand that his or her actions have predictable effects elsewhere and that what happens elsewhere affects them. Today, most Americans go from kindergarten through college without ever being taught how to trace causes forward or backward across space or to analyze spatial relationships in order to predict or explain.

Without this analytic ability, how would we ever expect them to make good decisions about where to live and work, how to transport themselves, what to buy and how to dispose of it, how to prepare for natural disasters, whether to go to war abroad, where to locate a store or factory, or how to market goods abroad? The list goes on and on.

An even bigger problem than the low rate of geographic literacy in this country is that Americans don't even know enough to see the price that they are paying individually and as a society. Most Americans don't have any idea how much better their lives and our world could be if they could all do geography. Once again, the largest group that does understand the value of geographic literacy is the community of GIS professionals, and that is why the National Geographic Society and ESRI want to enlist you in our long-term campaign to create a geographically literate society.

So, what have we done historically, where are we now, and where do we hope to go with your help?

Beginning more than 20 years ago, the National Geographic Society took up the cause of geographic literacy and created an education foundation to fund geography education initiatives. Since then, we established a national network of state "geography alliances," which are university-based organizations that advocate for geography education and provide professional development for teachers. Funded by a combination of proceeds from National Geographic programs, state governments, and private philanthropies, these alliances were successful in establishing K–12 standards for geographic literacy in all 50 U.S. states; Washington, D.C.; and Puerto Rico.

The state geography alliances also created geography education materials and trained thousands of K–12 teachers in their states. While teacher professional development is the key to improving geographic literacy, it is also the biggest challenge. Most teachers who are responsible for teaching geographic content, whether it's in the context of science or social studies, have never received any training in geography themselves.

In 20 years, the National Geographic-funded Alliance Network has had an impressive impact in raw numbers, but percentage-wise, it is just a drop in the bucket. That means, today, we face a situation in which we have a powerful infrastructure for reforming education, but we do not have the resources to bring about that reform.

For that reason, we are in the process of launching the second phase of our campaign for geographic literacy. The goal of this campaign is to approach universal geographic literacy. Specifically, we set a goal to achieve 80 percent rates of geographic literacy in all 50 states by 2025, where geographic literacy is defined as the ability of students to apply geographic skills and understanding in their personal and civic lives. We set a second goal to achieve 50 percent geographic fluency in all 50 states at the same time. Geographic fluency is a higher standard, which we define as preparation sufficient for successful postsecondary study in subjects that require geographic skills and understanding (e.g., international affairs or environmental science).

The year 2025 seems far away, but because educational reform is a slow process, and we don't currently have the necessary resources, this reform is an ambitious goal. To achieve our goal, we are working with the Alliance Network and other like-minded organizations, such as the Association of American Geographers, National Council for Geographic Education, and ESRI, on three parallel tasks:

- Create a combination of top-down policy and bottom-up consumer demand for geographic literacy.
- Obtain sufficient resources in the form of federal, state, and philanthropic funding to mount a large-scale reform effort.
- Create and implement plans for large-scale educational reform at the state and local levels.

There are important roles for GIS professionals and other applied geographers to play in all three of these strands, and in upcoming columns I will challenge you, the ESRI user community, to play your part.

(Reprinted from the Spring 2009 issue of *ArcNews* magazine)

Geography, GIS, and Mental Health

"Crossing Borders"

A column by Doug Richardson, Executive Director, Association of American Geographers

For those of you who were hoping this column might offer a groundbreaking treatise on the state of mind of geographers and GIScientists, you can stop reading here. I'm saving that project for when I retire.

What I would like to discuss here are the opportunities and needs for geography and GIScience to participate in the rapidly expanding field of mental health research, a relatively unexplored area for geographers but one in which geography and GIS can, I'm convinced, be a significant and potentially paradigm-changing contributor. It is also a research area in which geographers and GIS specialists can engage with and help address enormous human and societal needs.

As many of you know, the AAG has been working for several years to try to build relationships with the National Institutes of Health (NIH) on behalf of geography and GIS and help medical researchers in the many different NIH centers better understand what geography and GIScientists have to offer to the field of medical research. This work has continued to develop new inroads for geography at several NIH institutes, as well as in the broader medical research communities outside NIH. For example, the AAG and the NIH's National Institute on Drug Abuse (NIDA) have jointly sponsored special symposia at AAG's Annual Meetings during each of the past four years on the previously relatively unexplored research area of geography and drug addiction. That ongoing effort has now drawn attention throughout NIH and resulted in the publication of a book entitled *Geography and Drug Addiction,* which is being widely circulated in medical research circles and is available from the AAG.

The AAG's work on geography and drug addiction with NIDA has sparked further interest at other NIH institutes, including the National Institute of Mental Health (NIMH), regarding the potential for GIS and geography to also make contributions to the field of mental health research. We have been in lengthy and productive discussions with several NIMH researchers engaged in genomic studies that are attempting to identify genetic markers, the presence or absence of which, it is hypothesized, may correlate with various complex mental disorders, such as schizophrenia, depression, and so forth. The challenge here is that genetic factors are rarely determinant and are nearly always highly interactive with environmental risk factors.

This new genetic research has revived old debates about nature versus nurture, or genes versus environment, but at a whole new scale and level of detail and sophistication. As mental health and other medical researchers are increasingly able to obtain highly detailed and sophisticated genetic information, there is now also developing a counter-demand for more highly detailed and sophisticated information about the environment in order to attempt to sort out complex gene-environment interactions. This is where geography, with its emphasis on place and related geographic methodologies for organizing and understanding environments, and GIS, with its ability to integrate and correlate vast amounts of different environmental data with observed conditions, such as mental health disorders or genetic risk factors, become central to this new research.

Consequently, geography and GIS are now on the threshold of enabling substantial new breakthroughs in medical research involving complex gene-environmental interactions. We still have a long way to go in understanding genetic and environmental interactions, and our GIS systems and geographic methods are both challenged by the complexity of these systems. However, I have found that medical researchers everywhere, from NIH to universities to private companies, are highly receptive to the promise that geographic methodologies and GIScience and GIS systems hold for a better understanding of the etiology, treatment, and prevention of disease, addiction, and mental health disorders.

These explorations with NIH have been both interesting and productive. An illustration of the unexpected pathways and intriguing outcomes of these creative interactions between geography and the medical and mental health researchers at NIH is an invitation I received last fall to help organize a special session, together with others from NIH, on the topic of Geography, Addiction, and Mental Health for a meeting of the International Federation of Psychiatric Epidemiologists, which was held in Vienna, Austria. While generally not at a loss for words, I must admit that at first I was not sure what I should say (or not say) to a room full of psychiatrists. However, the meetings went very well, and there was genuine excitement on the part of the many psychiatrists, geneticists, psychologists, and medical researchers present in learning more about GIS and about geography's potential contributions to research on understanding the role of place and the environment in mental disorders and their treatment.

Examples of the dozens of research themes with geographic dimensions we discussed included genetic and environmental interactions in schizophrenia, research on the consequences of refugee displacement, psychiatric morbidity of homelessness, psychopathology among Holocaust survivors and their children, urbanicity and psychoses, the global economic burden of mental disorders, public policy and the measurement of happiness, and searching for genes with environmental interactions in complex disorders. Plans are under way to follow up both organizationally and individually to help link these research programs with geography and GIS.

As one NIH scientist noted at our session, "To date, most mental health research has focused largely on biomedical pathways. Increasingly, however, researchers are considering how people's environments—the physical and cultural contexts in which they live—influence the prevalence and consequence of mental health disorders." The AAG will continue to engage these issues of geography's potential role in medical research at all institutes of NIH, and I encourage geographers, GIScientists, and GIS specialists to also consider how you might work together with researchers at NIH's National Institute of Mental Health to help address these complex but pressing mental health research and human needs.

For More Information

Contact www.aag.org or www.nimh.nih.gov.

(Reprinted from the Summer 2009 issue of *ArcNews* magazine)

The National Geospatial Advisory Committee: An Action Agenda

By Anne Hale Miglarese, NGAC Chairperson

In January of 2008, U.S. Secretary of the Interior Dirk Kempthorne announced the formation and membership of the National Geospatial Advisory Committee (NGAC). This announcement came as no surprise to geospatial professionals following the activities of the Federal Geographic Data Committee (FGDC) or spatial data development and coordination in the United States. In fact, for years, many nonfederal organizations and individuals have called for a voice to officially provide input into U.S. federal government activities related to geospatial programs.

For the most part, the federal government was quite willing to receive informal input and hold forums to discuss its spatial activities, but listening was often an ad hoc and casual process. In defense of the government staff, federal law restricts the influence of nonfederal individuals on official federal programs and activities. Their informal approach was the only approach legally possible without setting up what is known as a federal advisory committee under the authority of the Federal Advisory Committee Act (FACA).

Illustration by Marina Murad, ESRI.

But, by formally establishing this FACA committee, i.e., the NGAC, the federal government can now receive formal advice and recommendations from representatives of state, local, regional, and tribal governments, as well as academia and the private sector.

The pending establishment of the NGAC was published in the *Federal Register* on May 16, 2007, along with a request for applications for committee membership. Thus, on January 29, 2008, the secretary officially named 28 individuals to serve on the NGAC (see table at the bottom of this article). These members represent a very diverse and exceptionally talented group of professionals who have spent many years devoted to promoting and advancing the use of GIS technology to improve decision making across many disciplines.

Governance

The charter for the committee was established by the office of the Secretary of the Interior and establishes that the committee will report to the chair of the FGDC, which is the Secretary of the Interior or his designee. Jim Cason, the Associate Deputy Secretary of the Interior, serves as the chair of the FGDC. The scope and objectives of the committee are also laid out in the charter:

"The committee will provide advice and recommendations related to management of federal and national geospatial programs, the development of the National Spatial Data Infrastructure [NSDI] and the implementation of Office of Management and Budget [OMB] Circular A-16 and Executive Order 12906. The committee will review and comment on geospatial policy and management issues and will provide a forum to convey views representative of nonfederal stakeholders in the geospatial community."

The committee will meet three to four times per year, and all meetings of the committee will be open to the public, with time devoted on the agenda for public comment. The chair of the NGAC, in consultation with the designated federal official (Ivan Deloach, Staff Director of the FGDC), will set the agenda and meeting dates. All meetings are announced in the *Federal Register,* and all documents and minutes of the meeting are publicly available on the Web (www.fgdc.gov/ngac).

Direction and Guidance from the FGDC Chairperson

The committee's first full public meeting occurred April 15–16, 2008, in Washington, D.C. At this meeting, Cason formally requested that the committee provide advice on

- National Spatial Data Infrastructure: Recommendations on the future roles and responsibilities of the key players in developing and sustaining the next generation of the NSDI
- Public-private partnerships and investment strategies: Recommendations on minimizing/removing investment barriers that impede public-private partnerships in advancing the collection, use, and dissemination of geospatial data, products, and technology

- Management of federal geospatial resources: OMB Circular A-16—Comments/ Recommendations on geospatial life cycle management strategies and revisions to OMB Circular A-16 data themes being developed and coordinated through the Geospatial Line of Business initiative

- Data initiatives: Reviews and recommendations, including recommendations on prioritization of specific programmatic or data initiatives, which include the following: Imagery for the Nation (IFTN), national land parcel data, and the *National Map*

At this meeting, the committee received briefings from federal staff on several general activities, such as an overview of FGDC activities; a general introduction to the Geospatial Line of Business activity and OMB Circular A-16; and an introduction to the *National Map,* Imagery for the Nation, Elevation for the Nation, and Geospatial One-Stop.

Additionally, significant time was spent allowing each member of the committee to express their views, concerns, and passions related to the work of the committee. From this three-hour discussion, many similarities emerged, and the cohesion of the group began.

Getting Started: An Action Agenda

The committee has been a long time in the making and hopes its efforts are not judged by the impact it makes in the first few months but by the quality of the advice and guidance it provides to the chair of the FGDC in the years to come. It is anticipated that the committee will focus on a wide range of topics over the next two years. Many of these issues and subjects may be studied and reported in short order. Many will take more time, and several should be viewed as long-term projects requiring detailed analysis and discussion.

Agenda items raised as actions in the first meeting were assigned to subcommittees, then brought back to the full committee for its endorsement in the June meeting. One such item was the creation of a mission statement:

The National Geospatial Advisory Committee mission is to provide strategies regarding the creation, management, and dissemination of cohesive geospatial data, information, and knowledge to enable commercial, academic, and nonprofit organizations and all levels of government to more effectively

- Empower and serve the public.
- Protect our homeland.
- Foster economic growth.
- Advance science.
- Manage our resources.
- Prepare for and respond to emergencies.
- Govern our nation.

NGAC Endorsement of Imagery for the Nation

With a mission statement complete, the committee was asked by Cason to evaluate and make recommendations on the Imagery for the Nation initiative. After hours of debate, the following statement was endorsed by the NGAC:

Whereas seamless coverage orthophotography has been demonstrated to have crosscutting utility; whereas all levels of government are currently investing in orthophotography, many without coordination or leveraging the investment; and whereas IFTN

- Provides financial incentives for all levels of government to cooperate in creation and publication of public domain data
- Saves taxpayer money by achieving national economies of scale
- Sets minimal technical standards ensuring that cohesive national data is created, while allowing buy ups so that varying state, local, and regional requirements can be met

- Establishes a regular schedule for delivery so customers and partners can plan
- Is the model for the development of other critical national geospatial data layers

NGAC fully endorses the concept of Imagery for the Nation. However, before it is authorized and implemented the following issues need to be resolved:

- A procurement strategy that uses a best practices procurement process and delineates the contracting agency(s), procurement methods, and vehicles must be detailed. This procurement plan should cover small business participation. The federal community should clearly speak to the intent of whether this information will be procured to create information that will go into the public domain or will be licensed as data products. Further, the government needs a funding and acquisition timeline that allows private companies to engage in strategic planning for capital equipment acquisition and staffing that allows the demand to be met in a timely fashion without creating undue risk of oversupply in the marketplace due to the lack of a clear procurement strategy.
- The committee requested a clear statement of policy from the federal government on how it intends to ensure that funding associated with the IFTN initiative will be monitored to make certain it is not used to underwrite projects that compete with private-sector services offered in the geospatial community.
- The development and publication of an integrated strategy for funding and implementing the data development initiative of the NSDI are critical. While it is acknowledged that the IFTN initiative is thoughtfully conceived and well vetted within the geospatial community, largely due to the efforts of the National States Geographic Information Council and the National Digital Orthophotography Program, it is important that this program not be implemented without careful consideration of the other data initiatives developing within the community. Specifically, the other programs that should be analyzed and synchronized with IFTN include Elevation for the Nation, Parcels for the Nation, and Transportation for the Nation. The geospatial community must analyze these activities and develop a plan to present them as needed investments in the development of information infrastructure in a thoughtful, complementary, and nonduplicative process.

- The recently established National Land Imaging Program (NLIP) is designed to meet U.S. civilian moderate-resolution land imaging needs to monitor the changes in land surface, polar regions, and coastal zones due to the changes in population growth, development, and climate changes. A program office has been established in the Department of the Interior, reporting at the secretary and assistant secretary level, to provide focused leadership and management for the nation's land imaging efforts. NLIP will focus on maintaining a core, operational government commitment and capability to collect moderate-resolution land imagery through the procurement and launch of a series of U.S. owned satellites, thereby ensuring the continuity of U.S. collected and managed Landsat-like data well into future decades. It is important for FGDC and the Department of the Interior to ensure that the IFTN and NLIP programs are clear in their mission focus and work together to provide society with the spatial information required to support decision making, albeit at very different scales for different applications.
- With regard to the management of Imagery for the Nation, the committee requested that the federal government clearly articulate the management process that will govern Imagery for the Nation as an ongoing program. Specifically, how will it be managed and by what agencies and offices; how will the programmatic staff stay in touch with the needs of the nonfederal user community; how will the program minimize duplication of effort and ensure through a vigorous outreach program that others are aware of the availability of this information; and, finally, how will the staff continue to measure the return on investment and document cost savings on an ongoing basis?

The committee looks forward to a regular dialog with the organizations promoting Imagery for the Nation, particularly FGDC. While there are still several issues as delineated above, the committee is confident that by working together it can achieve its common goal.

Transition Team White Paper

In the first meeting, a significant amount of dialog revolved around the geospatial community's need to engage in the political process by embracing a new administration in November and working to influence this new leadership to embrace geospatial technology as an investment that underpins the national governance structure and to positively influence hundreds of administrative initiatives to follow. The goal of this project is for a *geospatial* white paper to be developed for the transition team shortly after the November election. The design of the geospatial white paper will be simple and focus on why geospatial technology matters to the federal government, a few high-profile activities that could be embraced by the new administration, and the location and title of presidentially appointed positions within the federal agencies that have traditionally had significant influence on geospatial policy and technology. The subcommittee will be working over the summer on fully developing the transition paper, and the full committee anticipates finalizing the document at its October meeting.

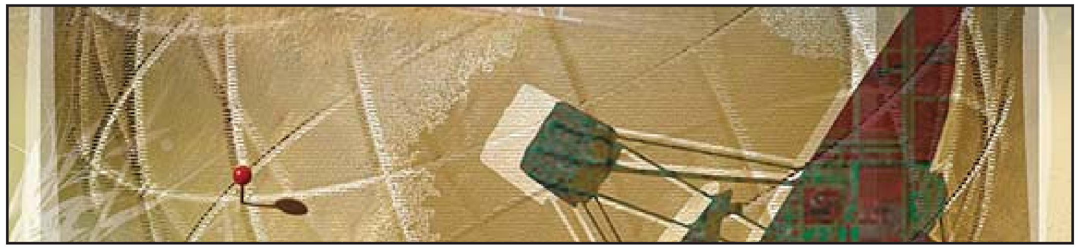
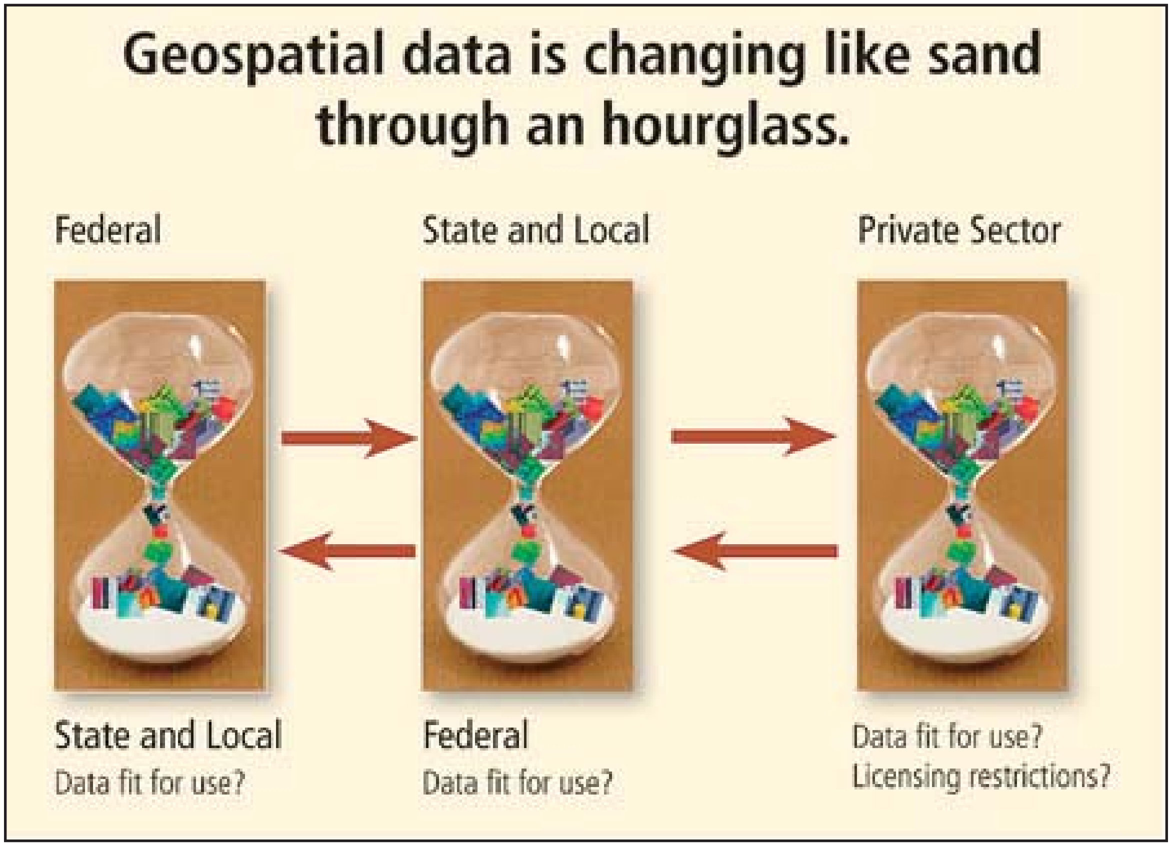


Illustration by Suzanne Davis, ESRI.

The Changing Landscape

Also, during the committee's first meeting, there was significant discussion on how the geospatial world has changed dramatically over the past decade and how, as a community, it must acknowledge that change and anticipate the future to make sound recommendations for geospatial investments in the public sector. These changes have occurred at all levels in government, academia, and the private sector. To lay a foundation and context for the NGAC deliberations over the next few years, the committee is developing *a changing landscape* white paper that describes this change from a technical level, a social level, and a governance standpoint. There are many everyday examples; all one has to do is look at how geospatial technology is being embedded in consumer applications on cell phones to see the change.

Perhaps the best example of this fundamental change occurring within the spatial community is to look at the progression of where framework spatial data is generated. In years past, most mapping data was generated at the federal level through federal programs, eventually making its way to state and local governments. However, often, the data was out of date by the time it was distributed to nonfederal governments or, even more typically, was not built to standard scales necessary at the state and local levels. One could argue that about 10 years ago, the hourglass began to turn and the flow of data began to move from state and local government, where the higher-resolution data was procured, to the federal government (*see hourglass graphic on page 90*). This transition alone has caused serious issues with governance structures that the community grapples with to this day. However, perhaps the most radical assertion of change has just begun. With the influence of Garmin, Google, Microsoft, NAVTEQ, Tele Atlas, Yahoo, and many other talented and financially enabled businesses moving into the local search arena on the backbone of geography, it is certain that this is only the beginning of this changing paradigm of where data is created and where partnerships are located.



In years past, most mapping data was generated at the federal level through federal programs and then eventually made its way to state and local governments. However, often the data was out of date by the time it reached nonfederal governments or was not built to the scales needed by state and local governments. About 10 years ago, the hourglass began to turn and the flow of high-resolution data began to move the other direction, from state and local governments to the federal government. Furthermore, perhaps a more radical change has just begun—the influence of private-sector data.

These fundamental changes and the influence and impact they will have on federal, state, and local governments, as well as the flow of geospatial goods and services, cannot be underestimated. The National Geospatial Advisory Committee will endeavor to describe and analyze many of these phenomena in the white paper to be published later this year.

The Long-Term Agenda

In light of the transition occurring within the geospatial industry, the committee spoke at length on the need for a national strategy for building and sustaining the NSDI. There is broad agreement on the need for such a strategy, which is certainly the long pole in the geospatial tent. This effort will take substantial discussion, listening, learning, and debating to be thoughtfully constructed. Deliberations will focus on topics such as the need for strong leadership within federal, state, and local governments. It is ideal that all these entities are represented on the NGAC. Sustainable funding and financing must be a major component of the strategy, and within this topic, the analysis of business models that allow true public-private partnerships will certainly be an interesting debate.

Finally, the geospatial community must work together to attract and educate the next generation of this profession. This country's attention to the basic teachings of geography and the many other disciplines that underpin geospatial technology is woefully inadequate. This basic framework for a national strategy for the NSDI will evolve and include building the components of the strategy in consultation with the community at large.

Staying in Touch

FGDC encourages you to monitor its activities through its Web site (www.fgdc.gov/ngac). The committee is in the process of developing an outreach strategy and hopes to release it on its Web site in the near future. It looks forward to working with the geospatial community to provide actionable recommendations and advice that promote better decision making through geography.

About the Author

Anne Hale Miglarese is a principal with the Booz Allen Hamilton consulting firm in Washington, D.C. Miglarese has worked in state government with the South Carolina Department of Natural Resources and in federal government with the National Oceanic and Atmospheric Administration. Most recently, she was the president and managing director of Fugro EarthData. Miglarese also serves on numerous boards, including the Management Association of Private Photogrammetric Surveyors and TerraGo Technologies. Miglarese is the chairperson of the National Geospatial Advisory Committee.

Academic and Private-Sector Representatives	**Public-Sector Representatives**
Sean Ahearn, Hunter College, City University of New York	Timothy M. Bennett, NativeView
Allen Carroll, National Geographic Society	Michael Byrne, State of California
David Cowen, University of South Carolina	Donald Dittmar, Waukesha County, Wisconsin
Jack Dangermond, ESRI	Dennis Goreham, State of Utah
Kass Green, The Alta Vista Company	Randall L. Johnson, Metropolitan Council, St. Paul, Minnesota
David Maune, Dewberry	Randy Johnson, Hennepin County, Minnesota
Anne Hale Miglarese, Booz Allen Hamilton (Chairperson)	Jerry Johnston, U.S. Environmental Protection Agency
Charles Mondello, Pictometry International	Barney Krucoff, District of Columbia
Kim Nelson, Microsoft Corporation	Timothy Loewenstein, Buffalo County, Nebraska
Matthew O'Connell, GeoEye	Zsolt Nagy, State of North Carolina
John Palatiello, Management Association for Private Photogrammetric Surveyors	Jay Parrish, State of Pennsylvania
G. Michael Ritchie, Photo Science	Gene Schiller, Southwest Florida Water Management District
David Schell, Open Geospatial Consortium	Steven Wallach, U.S. National Geospatial-Intelligence Agency (Vice Chairperson)
Christopher Tucker, ERDAS, Inc.	

(Reprinted from the Summer 2008 issue of *ArcNews* magazine)

Global Dialogues: GIScience and Sustainable Development in Africa

"Crossing Borders"

A column by Doug Richardson,Executive Director, Association of American Geographers

The Association of American Geographers recently had the opportunity to participate with hundreds of African geographers, GIScientists, and environmental scientists in a new dialogue around the theme of Geospatial Science and Sustainable Development in Africa. These discussions, which were initiated in March 2008 and have already generated several promising new areas of research and educational collaboration, were sponsored by the U.S. Department of State's Global Dialogues on Emerging Science and Technology (GDEST) program. Follow-on activities and continuing interactions resulting from these dialogues have the potential to generate considerable ongoing and long-term cooperation among African and U.S. scientists in geographic research, geographic information science (GIScience) education and GIS applications, sustainability science, and many related fields.

Five other GDEST programs also have been undertaken, including dialogues in Japan (focusing on nanotechnologies), China (biotechnology), and Germany (quantum computing). However, the recent Africa GDEST program is the first to be initiated on a continental scale and the first to address geography-related research fields, such as geospatial science and sustainability.

The Global Dialogues on Emerging Science and Technology program focusing on Geospatial Science and Sustainable Development in Africa began in March 2008 with site visits to universities, governmental ministries, and nongovernmental organizations in nine African countries, followed by a conference on the same theme in Cape Town, South Africa.

The U.S. delegation was divided into two teams, East Africa and West Africa, and included members from the U.S. Department of State Humanitarian Information Unit and its Bureau of Oceans and International Environmental and Scientific Affairs, as well as representatives from other

U.S. governmental agencies, several U.S. universities, the American Geographical Society, the Association of American Geographers, and the United States Agency for International Development (USAID) regional offices. The teams conducted more than 50 site visits and met with hundreds of African experts in the fields of environmental remote-sensing interpretation and modeling, GIS cartography and analysis, agriculture, education, health, surveying, mining, climate, hydrology, population, urban systems, and information and communication technology.

Care was taken to listen to and learn from our African colleagues, to identify needs rather than prescribe solutions, to build upon existing regional capacity in geospatial science and technology rather than duplicate or displace it, and to explore opportunities for collaboration between U.S. and African scientists and institutions, as well as among African organizations and networks, in ways identified as useful to scientists, educators, and governmental agencies from the region.

It was clear from both the country visits and the conference that significant progress has been achieved since the 2002 World Summit on Sustainable Development in terms of the diffusion and sophistication of geospatial technologies, applications, and coordination, both regionally and in individual countries, and their use in sustainable development planning and program implementation. Despite progress, however, optimal use of geographic information science and associated technologies is often constrained by a lack of resources, a lack of access to suitable data, and a lack of coordination among users and data producers.

Among other topics, GDEST participants particularly sought to promote future dialogues that would identify partners for collaboration on specific projects or programs; make better use of collaboration among U.S. and African scientists and practitioners to create a sustainable critical mass of African expertise; support regional and indigenous educational and institutional infrastructures; and develop educational and research collaborative mechanisms, including faculty and student exchange programs, online interactions, and better access to research and curricular information.

The AAG currently is implementing some of the above resource sharing and online interactive coordinative mechanisms through its new subsidized Developing Regions Membership Program and through the existing AAG Center for Global Geography Education programs.

Also important to sustaining collaboration is supporting existing African networks of excellence and platforms for dialogue, information sharing, and communication. For example, African networks of excellence, such as the African Association of Remote Sensing of the Environment

(AARSE), African Geo Information Research Network (AGIRN), African Reference Frame (AFREF), Environmental Information Systems Africa (EIS-AFRICA), Mapping Africa for Africa, and university networks (e.g., University Network for Disaster Risk Reduction in Africa [UNEDRA]), are vital infrastructures of communication and coordination for research, education, and applications collaboration. Descriptions of and linkages to these and many other existing African networks can be accessed directly through the AAG Web site at www.aag.org/developing.

The U.S. GDEST delegation representatives, both individually and in coordination with U.S. embassies in the countries visited, are currently following up on contacts and acquaintances made during the site visits and will be continuing discussions on specific projects for which opportunities for partnerships and collaboration were identified. A report on the African GDEST program's progress and findings is under development and will be made available in the near future.

I would like to thank Lee Schwartz, director of the Office of the Geographer and Global Issues at the U.S. Department of State, together with Nina Fedoroff and Andrew Reynolds of the Office of the Science and Technology Adviser to the Secretary of State, for providing key leadership and logistical support essential to the success of the African GDEST program. Most importantly, on behalf of all of the participants, I would like to express our deep appreciation to our African colleagues for the opportunity to learn from them during these dialogues and for their insight and guidance on how to sustain ongoing interactions and useful collaborative activities in the years ahead.

More information on African geography and GIS research, education, and sustainable development activities, as well as collaborative needs and opportunities, is available and updated regularly on the AAG Web site (www.aag.org).

(Reprinted from the Spring 2008 issue of *ArcNews* magazine)

Get Involved with Geo-Education Reform

"Geo Learning"

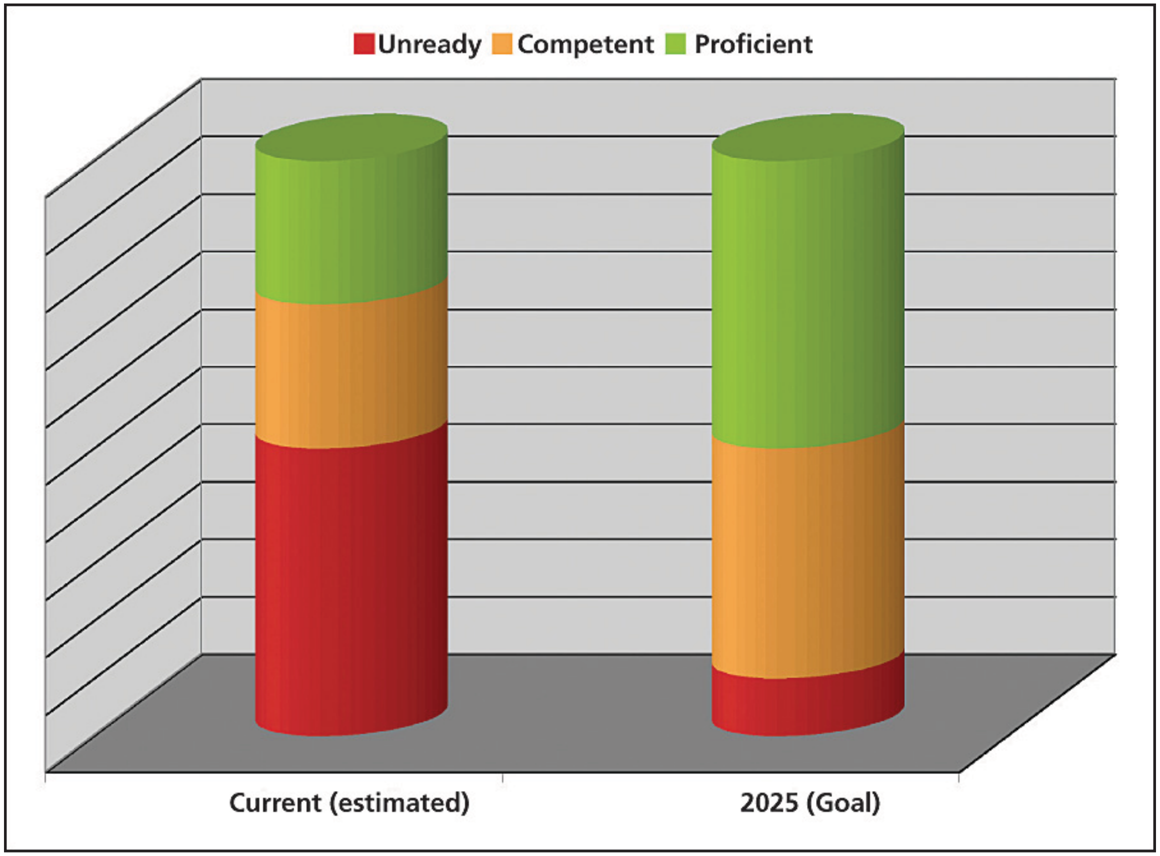
A column by Daniel C. Edelson, Vice President for Education, National Geographic Society

We've got a problem in our country. The rate of geographic literacy—meaning the number of people who can synthesize geographic information from a variety of sources and draw a sound conclusion—is abysmally low. On the other hand, *ArcNews* goes to almost a million individuals who earn their living by doing that kind of geographic reasoning every day.

So, what we have is an enormous geographic literacy gap. We have a solid core of geographic experts, including the readers of *ArcNews,* but once we get outside that group, there is a dramatic drop-off in the level of geographic understanding and skills. As the companies and agencies that are struggling to fill openings for GIS professionals can attest, we can certainly use more geographic experts in our country. However, from a societal perspective, I believe the gap in expertise between experts and the rest of the population is a much bigger problem.

For our society to function effectively in the modern world, we need the vast majority of our population to be either *geographically competent* or *geographically proficient.* These are terms I use to describe nonexpert levels of geographic literacy. Geographically competent describes individuals who are prepared for everyday geographic reasoning, such as choosing where to live or evaluating a ballot initiative that would affect land use. In a well-functioning school system, most students would achieve geographic competence by the end of middle school.

Geographically proficient describes college readiness in geographic skills and understanding. A geographically fluent individual is prepared for college-level coursework in subjects that require geographic skills and understanding, such as international relations or environmental science. At the National Geographic Society, we have set the goal of achieving a 50 percent rate of geographic fluency among 18-year-olds by 2025.



A rough estimate of the distribution of geographic literacy among 18-year-olds in the U.S. today (left) and the distribution that National Geographic *is committed to achieving by 2025 (right).*

While there are no statistics on the distribution among different levels of geographic literacy in the United States, there is pretty good evidence that a majority of Americans are not geographically competent. Our goal is to flip this distribution over the next couple of decades. Furthermore, our goal is to have the geographically proficient population be the largest, followed by the geographically competent and geographically expert populations.

One reason that increasing the rate of geographic literacy is more important than increasing the number of geographic experts is that the public is the audience for the work of geographic experts at the end of the day. We can no longer afford for corporate executives, policy makers, politicians, and even the general public to be uneducated about geographic planning and decision making. If they are, then the work of geographic experts is largely wasted. Of course, the other reason is that if we increase the supply of individuals at the other levels of geographic literacy, then the pool for geographic experts gets larger.

If we are serious about reducing this geoliteracy gap, then the question we have to ask ourselves is, Where is the solution to this geoliteracy gap going to come from? It is not going to be solved by the majority. The majority are not even in a position to understand what they are missing. The solution is going to come from the people who can see the price that our society is paying on a daily basis for the lack of geographic literacy among its citizens. It is going to come from the relatively small minority of geographically literate individuals, especially the geographic experts.

So, what actions can individual GIS professionals and other applied geographers take to help move along the incipient campaign to boost geographic literacy?

The first action is personal. It is important that we start building public awareness of why geographic literacy is so important and what a good geographic education would teach our children. Those of us who "do geography" on a daily basis need to start talking to the people in our families and communities about what we do, so they start to understand that geographic literacy is not about knowing where things are but about knowing how to plan and make decisions.

By talking to our family and friends about the kind of geographic problem solving we do, we can start to help them see what their children are missing in their educations. It is possible to talk to people about the kinds of work that GIS professionals do without using terms like symbology, constraint satisfaction, buffer, and model. It can be good practice for us and eye opening for them.

The second action is political. At both the state and federal levels, it is important that people who understand the importance of geographic literacy advocate for improved geographic education in our schools. As a result of hard work by a large number of "geoevangelists," all 50 states, the District of Columbia, and Puerto Rico have social studies, science, and technology standards that call for geographic literacy. However, these state standards are revised every few years, and if we don't stay vigilant, they can be changed. If you are interested in finding out about the current policy situation in your state, you can contact your state geographic alliance (find yours at www.ngsednet.org/communities).

At the federal level, there is legislation pending in Congress right now to establish a fund for the improvement of geography teaching. Geography is the only subject listed in No Child Left Behind as a core academic subject that has no federal funding program. The bill in Congress, called the Teaching Geography is Fundamental Act, has strong bipartisan support, but it will not pass unless legislators know that there are constituents who care. All it takes is a few minutes to make a phone call or write a letter, and it can make a huge difference. National Geographic has information about the bill and how to contact your legislators at www.nationalgeographic.com/foundation/policy_initiative.html.

The third action is educational. There are valuable roles for geography professionals to play in their local educational system. Many GIS professionals teach at community colleges and in professional seminars. This is very important for filling the pipeline for geographic experts, but there are things we can do in the K–12 system that will start to boost the numbers of geographically competent and proficient individuals. However, finding and developing opportunities to work in schools can be tricky. So, National Geographic and ESRI are teaming up on a GeoMentoring program to pair geography professionals with K–12 teachers to bring their expertise into the classroom.

At the ESRI International User Conference this summer, we will be introducing this new program that will provide geography professionals with guidelines for working with schools and materials for activities they can do with teachers in their local schools. These activities will range from "pre-GIS" activities using paper maps, crayons, and cutouts for lower grades and schools with limited technology access to real GIS activities using ESRI software in schools.

The fourth action is financial. In most of the scientific disciplines, a substantial stream of funding for educational improvement comes from scientists and the companies that employ them. Over time, the cause of geographic literacy is going to require that same level of support. In a future column, I will describe some giving opportunities for individuals and organizations to support the improvement of geographic education at local, state, and national levels.

In closing, I have two points to make. One is that the problem is urgent. The second is that the solution we are seeking will, at best, come slowly and only through serious and prolonged effort. There are things that we, as geographic experts, can and should do today, and I encourage you to begin right away. I must also caution you, though, that improving education is more about tortoises than it is about hares. So, if you do talk to a neighbor, call your senator, or become a GeoMentor, don't do it as a quick fix. Be prepared to stick with it for a while. If we all do, we will be able to make a change.

(Reprinted from the Summer 2009 issue of *ArcNews* magazine)

Since 1969, ESRI has been giving customers around the world the power to think and plan geographically. The market leader in geographic information system (GIS) solutions, ESRI software is used in more than 300,000 organizations worldwide including each of the 200 largest cities in the United States, most national governments, more than two-thirds of Fortune 500 companies, and more than 5,000 colleges and universities. ESRI applications, running on more than one million desktops and thousands of Web and enterprise servers, provide the backbone for the world's mapping and spatial analysis. ESRI is the only vendor that provides complete technical solutions for desktop, mobile, server, and Internet platforms. Visit us at www.esri.com.

ESRI • 380 New York Street • Redlands, CA 92373-8100 • 909-793-2853 • FAX 909-793-5953 • www.esri.com

G37018
ESRI6/09sp