Digital Maps: An Essential Part of Every Citizen's Interface to the NII

An Open GIS Consortium (OGC) White Paper

by Lance McKee Open GIS Consortium

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1 Goal: Integrate the NSDI and the NII, for Every Citizen

The National Spatial Data Infrastructure (NSDI), when opened up through geoprocessing interoperability interfaces based on the Open GIS Consortium's (OGC) OpenGIS(TM) Specification, will expand out of the domain of geographic information system (GIS) experts into the day-to-day lives of the general population. OGC's research and development goal is the development of the OpenGIS Specification.

One goal of others in the NII research and development community ought to be to examine the ways in which digital spatial data (geodata) can be most effectively used by citizens in their everyday wayfinding and transportation, electronic consumer purchasing, education, and interactive entertainment, and also in the many existing and future jobs that will involve geodata and geoprocessing. Another research goal ought to be to seek new ways in which designers of virtual environments and visualization tools can make use of humans' spatial visualization abilities, including our almost innate ability to understand maps and aerial views.

Taking a longer psychological, social, and historical view of Every Citizen, we should also research the various "media effects" of digital maps. Maps of all kinds powerfully condition our thinking about the world beyond our immediate viewspace. Geographic information systems (GIS), which enable interactive viewing and intersection of multiple spatially coincident maps representing diverse cultural and natural themes, promote holistic, cross-disciplinary thinking. Widespread viewing and use of geographic information potentially promote broad public global awareness in the same way that views from orbiting spacecraft expand the world views of astronauts, as reported by astronauts. If we assume that human-machine interfaces and interactions affect consciousness, and if we care about the evolution of consciousness, we ought to study and characterize these effects with an eye toward developing high level design principles that support development of interfaces and uses that nudge us toward greater awareness of our relationships with each other and our planet.

2 Market drivers and technology drivers that make these research issues significant

Various market drivers and technology drivers are converging to make geodata and geoprocessing a much more important part of the NII.

Market drivers:

Current producers of geoprocessing software have long looked for an expansion of their markets commensurate with the benefits their technology has to offer in many segments of society. That expansion has been inhibited by non-interoperability and difficulties in sharing data held in diverse proprietary formats. OpenGIS interfaces will remove those barriers.

Society has a growing need for geoprocessing due to growing population and worsening environmental problems, geographically distributed government and business activities, rapid globalization of many markets and activities, and increasing pressure on businesses, governments, and individuals to operate more efficiently.

There is a growing realization that much data (70%-85% of data in all databases) has a spatial component which can exploited in a variety of ways for more effective analysis and display.

Technology drivers:

Faster CPUs and high performance image processing and graphics processing finally provide a base capable of supporting distributed geoprocessing, which often involves intense computation and large data files. Wider bandwidth networks and distributed computing infrastructure (OLE/COM, CORBA, Java, etc.) and middleware and componentware architectures are important because so many geoprocessing applications benefit from transparent access to remote geodata stores and remote specialized geoprocessing functions, and from integration of geoprocessing functions into other workflow. "gIS" with a lower case g expresses the potential for open systems architectures and object technology to enable integration of geoprocessing as one (increasingly cost effective) subordinated component of applications and decision support systems. Growth in the use of geoprocessing will occur as middleware and componentware approaches release geoprocessing from the confines of large, expensive, complex monolithic software systems.

Geoprocessing technology is proceeding as rapidly as the general computing telecommunications technologies, and not only in the area of geoprocessing interoperability interfaces. All of the following support the wider use of geodata and geoprocessing by Every Citizen: powerful spatial database technologies introduced by major database vendors; smaller and cheaper geographic positioning systems (GPS); sophisticated, inexpensive, and abundant commercial Earth imaging data products; advances in digital orthophotogrammetry for satellite Earth imaging and aerial still and video imaging; continuing specialization and product differentiation in the areas of GIS, CAD, and digital cartography; distributed interactive simulation; and three-dimensional spatial data visualization techniques (including interactive virtual reality approaches). These technologies hybridize in many ways. For example, high resolution satellite images and digital orthophotogrammetry permit quite precise automatic generation of three-dimensional views of the Earth's surface.

3 As geodata accumulates, the need for geographic interfaces grows

Simple geodata accumulation is also a driver. There is only one Earth, and the set of all geodata is referenced to this one finite spherical volume, like a rapidly growing onion of thematic maps of cultural and natural phenomena. As network-accessible geodata accumulates in tens of thousands of archives around the world, it becomes an ever-richer, ever more significant basis for an ever-growing number of local and global activities. It becomes one of the foundations of the new world culture of the Information Age.

4 Network-based geospatial information will serve many purposes

Below are some examples of how network-resident geodata and geoprocessing resources will be used by Every Citizen. Most will involve simple, specialized, stylized interactive map displays. A set of research issues can be derived by examining the user interface requirements of categories of applications, such as simplicity, information density, interactivity modes, etc.

Citizens will use the NII to help them get from A to B. Geographic positioning systems (GPS) in car and cell phone will provide the coordinates of A, and the car's map display and the cell phone's multimedia yellow pages will show the way to B. The necessary geodata will be stored remotely and downloaded on demand, transparently to the user.

Geoprocessing middleware and componentware will compare the distances to multiple possible destinations. The multimedia yellow pages, for example, will show driving time or walking time to a selected set of nearby restaurants. The software need not be stored permanently in the information appliance.

Not just car drivers, but hikers, boaters, and visitors to a city will see on a little screen where they are, and how to get to where they want to go.

A numbered package en route from A to B will show up on a digital map display, showing where it is now on its route. (Some shippers already provide this service.) People waiting for buses and airplanes will see where the bus or airplane is, on a digital map, with estimated minutes till arrival.

More than seventy percent of database records contain spatial information. Every database and spreadsheet, and the compound documents and work environments in which these functions are embedded, will be able to make maps based on spatial information (usually street addresses) in data records. Spatial display and analysis will be important in many workflow scenarios.

Listed below are other geographic applications used by Every Citizen during daily life. Each has particular user interface requirements:

- Education/training, distance learning, research collaboration
- Electronic libraries, electronic museums and galleries
- Online government geographic information for informed citizens
- Maintenance of the individual's information context and connection (personal logical network) as the individual moves through space, bridging media and modality; mapping electronic locations of devices (addresses) to their physical locations; using concepts of reach space, co-location, and near-by.
- Virtual reality landscapes from Earth images for interactive entertainment
- Security monitoring and intrusion response
- Special wayfinding for elderly and disabled
- Product distribution/warehousing optimization
- Intelligent vehicle highway systems (IVHS) and parking place location
- Traffic/weather information
- Route guidance and planning, multimodal trip planning, traveler services
- Locale-specific resources and recommendations for small farms and gardens
- City information services
- Finding jobs and clients available locally

Some geographic applications used by citizens in various jobs:

- Emergency road services and 911 emergency response systems
- Virtual reality landscapes from Earth images for: military, disaster relief, and rescue preparedness; civil engineering and landscape architecture
- Agriculture and forestry
- Climate research, agronomy, biology, ecology, geology, other sciences
- Urban and regional planning
- Automated mapping and facilities management
- Military surveillance
- Natural resource discovery, exploitation, and management
- Water resource management
- Parolee tracking
- Global and local environmental monitoring, advance of environmental sciences

- Support for "green" standards, local waste-as-resource arrangements
- Cable, microwave, and cellular transmission installation planning
- Telemedicine, better care for rural trauma victims
- Global maritime information and rescue system, air traffic control
- Commercial vehicle operations
- Business siting, market research, and other business geographics applications
- Geographic matching of prospective employees with available jobs, or prospective service providers with prospective clients
- Public administration networks
- Land tenure systems
- Precision farming (GPS-guided controlled delivery of nutrients and chemicals based on Earth imagery or automated GPS-located soil or crop sampling)

The number of applications for geodata is growing rapidly, and will continue to grow as the national and global spatial data infrastructures develop.

5 Maps are part of the pre-Net culture. New technologies take in old technologies. Old technologies become the stuff of metaphors.

Maps are a part of most cultures, because spatial thinking is an essential part of our relationship to our physical and cultural environment. Even in simpler cultures that don't pass down written records, individuals make temporary maps to remind themselves or show others how to find their way in unfamiliar territory. All birds and mammals form mental maps, and as cooperative hunter-gatherers, humans developed sophisticated spatial awareness and spatial communication abilities that came to support other cultural activities besides physical way-finding. For example, we say in a figurative sense that *we are on our way* to making the National Spatial Data Infrastructure an integral part of the National Information Infrastructure. User interfaces are collections of symbols and metaphors, and the map metaphor is inherently important in cyberspace. Basic research in spatial reasoning, spatial memory, and spatial communication would support development of better user interfaces that employ spatial display and manipulation.

Virtual reality will also help geodata users evaluate data sources. Because there is will be so much geodata available, and because geodata is often complex, we will often be concerned about geodata quality, content, and lineage. A system of geometric shapes could be used to represent certain content parameters, and their shape, color, and motion could represent quality parameters. A human computer interface could be a map or an image. Once you center on a spot you can call up various basic icons that represent data objects. It is easy on the Internet to find lots of data, but hard to sift through it. The interface ought to be able to tell Every Citizen easily and intuitively about the "goodness" of the data. For example: How does software communicate to a skier who wants to see the snow pack at eight Rocky Mountain ski resorts? The skier finds imagery, but it is summer data, not winter data, so an error signal intervenes. Through user configuration of simple preference files, the computer system knows that skiing requires winter data.

6 Digital maps are part of multimedia, virtual reality, and the change in our perceptions

Paper maps are a special form of printed communication, important to motorists, subway riders, explorers, scientists in many disciplines, historians, municipal service agencies, shippers, travelers, property owners and managers, and marketers. The utility of maps is amplified in several ways by computers and networks. A GIS, for example, is like multiple same-region overlaid thematic maps drawn on clear film, a visual-interface spatial database. You can query a GIS to meld thematic maps into a new map showing, for example, all the areas 3,000 feet or higher in elevation, within 50 meters of a standing body of water, within 1000 meters of a road, where most of the trees are pines, where the slope of the ground is less than 10%, and the population density of humans is less than 1 person per square mile. (More spatial temporal reasoning research needs to be done on how to articulate the conditions of a spatial search.) Digital technology allows: storage of (and network access to) huge quantities of geodata; zooming, panning, and other kinds of interactive manipulation which overcome the limitations of paper space and human visual acuity; real-time tracking; input from GPS and Earth observation satellites; and instant display of non-spatial data -- text, pictures, graphs, etc. -- associated with selected map features or locations.

Through paper maps, Every Citizen is familiar with graphic abstraction of large terrestrial spaces. Digital maps apply this helpful information presentation convention to vastly greater information domains. Digital maps and three-dimensional virtual fly-overs and fly-throughs will be an important part of many graphical user interfaces, because everyone intuitively understands maps and aerial views, and many kinds of information have a spatial component that makes spatial representation and visualization appropriate.

The new media that are "massaging," in Marshall McLuhan's term, our individual minds and collective culture away from text-induced linear, sequential thinking toward non-linear thinking characterized by multiple simultaneous modalities. Spatial display and analysis offer a visual, intuitive, effective means for solving a wide range of complex problems. Visualization of geographic information, or visualization of information geographically, helps people cope with information glut. Virtual reality applications will employ spatial representations of real spatial phenomena, but they will also employ spatial representations of non-spatial phenomena, simply because our brains are hardwired for solving problems in three-dimensional space. Important parts of the software and data for configuring and populating cyberspace will be borrowed from geoprocessing applications and geodata archives and data feeds. Similarly, research into spatial thinking will ultimately benefit both "real space" and cyberspace applications.

7 Research issues

Several research issues are identified in the text above. OGC's research and development in the area of geoprocessing interoperability is primary in the sense that spatial data will have a much greater role in the NII when diverse systems can exchange diverse kinds of data and access other systems' geoprocessing resources. Many applications will then be using geodata, and application developers will be looking for ideas and guidance concerning geoprocessing user interface development. Useful research will draw inspiration from traditional cartography and from general ideas about user interfaces.

Over the next twenty years, we will learn more about how people function while immersed or partially immersed in virtual environments. We will learn what problem simulation schemes work best, and what kind of problems are most fruitfully addressed by these schemes. Many of these environments, certainly, will include extended landscapes representing real or imaginary spaces, and the role of spatial reasoning, spatial memory, and maps will be of interest.

Everyone views the world differently. This is an issue for OpenGIS Specification developers because different geodata producers and users give the same geographic feature different names and sets of descriptive parameters, and different metadata. Part of the specification proposes semantic translators that domain experts from two different domains will configure to enable semiautomatic translation and integration of geodata. The problem is a difficult one. The problem is much broader than geodata integration, because computer users involved with other computer users need common interfaces to enable effective communication and collaboration. Map interface developers as well as other kinds of interface developers need to address the issue of standard symbology and usage.

Undoubtedly commercial research and development projects and market activity will generate many of the dominant productizable ideas and standard graphical and conceptual approaches.

Academia should take a longer view, that is: 1) address the cognitive and broader social effects of developments in the spatial sub-domain of the multimedia world, and 2) look in very basic ways at how user interface design can layer most elegantly on our legacy wetware and cultural firmware and leverage most powerfully a positive vision for the future. The government has a role in cataloging and tracking evolving research topics of all kinds and supporting those that best serve the nation and the world community. By participating as technology users in industry consortia (such as OGC) that include users in technology planning and specification efforts, government agencies can 1) ensure that the technology provider community meets agency needs and 2) influence the direction of technology that will become part of the larger economy and culture.

Lance McKee

Open GIS Consortium, Inc.
tel: 508-655-5858
fax: 508-655-2237
lmckee@ogc.opengis.org