The Next Generation of GIS

Dealing with design and space-time

The rapidly changing nature and scale of problems such as global climate change and the widespread failure of the banking system threaten to overwhelm the resources of individual nations and defy the methods of traditional science. However, leading researchers and practitioners of geospatial technology believe a new generation of GIS is evolving that will help understand and address these problems far more effectively.

Many of these leaders were recently brought together for a pair of related meetings held at the ESRI headquarters in Redlands, California. The first event, the 2010 GeoDesign Summit, was sponsored by the University of California, Santa Barbara; the University of Redlands; and ESRI. It was held January 8–10. More than 170 academics and professionals met to discuss GeoDesign, a new GIS field that marries the original conceptualization of GIS by Ian McHarg as a tool for designing the human environment with the natural one with the more familiar applications of GIS for data collection, creation, and management; data analysis; and decision support.

As ESRI president Jack Dangermond noted when introducing keynote speaker Thomas Fisher, this new field is exciting because it creates a "continuum between measurement and design." Fisher, the dean of the College of Design, University of Minnesota, approached the topic from the design side rather than the GIS side. He emphasized that GeoDesign should fulfill the real mission of design, which is "making things work better in the world," particularly as related to sustainability and social justice issues rather than just making things look more attractive, the popular impression of what design does. He also recognized that GeoDesign has a strong temporal element because it brings together geography, which looks at the "way the world is and was," with design, which looks at the way the world might be, connecting the past, present, and future. Also, he noted, geography and design both are fundamentally spatial disciplines.

Fisher said that historically, society has been designing without a lot of information on consequences—consequences to the environment, other people distant in time or space, and other species. The focus has been almost exclusively on fulfilling present needs. As GeoDesign can bring data to bear on these decisions "it will profoundly change the way we live and the way we inhabit the planet." (For more information on the GeoDesign Summit, see "Designing GeoDesign: Summit on new field that couples GIS and design," on page 16 of this issue.)

Developing tools for dealing with large-scale, complex problems was also the impetus behind the Space-Time Modeling and Analysis Workshop. Thought leaders from seven countries, who work in academia, government, and industry, met February 22–23, 2010, to share current work being done on this aspect of geospatial technology and develop an agenda for defining research areas and designing spatiotemporal tools going forward.

This workshop, cosponsored by the Association of American Geographers (AAG), the University of Redlands, the University of Southern California, and ESRI, was the first Redlands GIS Week event. The workshop included keynote presentations, Lightning Talks, and breakout sessions that identified the most important challenges and immediate strategies for incorporating space-time into GIS processes.

In his Keynote Address, Michael F. Goodchild, professor of geography at the University of California, Santa Barbara, and director of spatial@ucsb, observed that while "we have been talking about spatiotemporal analysis modeling for a number of years, we are now at a bit of a tipping point where we can really start making progress."

Spatiotemporal tools are "a way for looking at spatial data that will help us deal more effectively with the complex problems we now face, like climate change and economic meltdowns and infectious disease, that don't allow for a leisurely, reflective approach to solving them."

The geospatial approach has become more valuable because the role of the scientist and science in society have changed. The era of the lone scientific investigator is over. Discoveries about complex systems require teams of researchers who need powerful data acquisition and management systems coupled with sophisticated tools for handling both space and time.

Goodchild also believes that science must have a more active role in society and engage with policy making. To do this, the scientific community must package the results of science for general consumption. GIS is well suited to the task of bringing all the pieces of scientific understanding together in a way that can be comprehended by the public to influence policy. Policy and public interest are driven by change. This means getting and holding the public's interest is difficult with static maps. Incorporating the time dimension in GIS will make it more captivating.

In addition, every major issue has an associated time scale. Climate change occurs over decades, climate tipping points over years, and economic meltdowns occur in a matter of months, while infectious diseases span weeks and disasters are framed in days. The analysis and response to events has to speed up and occur in near real time.

One approach Goodchild suggested for developing spatiotemporal tools in GIS was to consider space-time as a collection of "sandboxes" or domains based on the tools, data, and assumptions of the team working in that area. How many areas or sandboxes are there? He introduced seven sandboxes for examining application areas for space and time. His remarks served as a starting point for much of the discussion over the following two days.

Workshop presentations explored the wide-ranging work being done across many fields, particularly transportation and health. David Maidment, director of the Center for Research in Water Resources, University of Texas at Austin, described the ambitious work of the Consortium of Universities for the Advancement of Hydrologic Science, Inc. (CUAHSI) on space-time for hydrology. CUAHSI represents more than 100 universities that develop infrastructure and services that advance hydrologic science and promote education in this area.

Integrating GIS, which describes the water environment of watersheds, streams, gauges, and sampling points, with water resources observation data that describes the water itself and consists of measurements such as flow, water level, and concentrations, is made most challenging because this observation data is not standardized at all.

"Connecting GIS data with observational data is connecting space and time," said Maidment. The point water observations time series CUAHSI developed combines a point location in space with a series of values in time and uses WaterML invented by CUAHSI for transmitting water data on the Internet. Using Web services, the consortium has the world's largest water data catalog, which accesses 4.3 billion data values. This system lies over existing water data systems and allows them to be seen as a whole. CUAHSI built a hierarchy of concepts to reconcile the meaning of variables used in observational data so data can be located without requiring special knowledge of the naming conventions of each organization that might supply that observational data.

In closing, Maidment identified the complex challenges of space-time. He noted that time is subtle: although it's really continuous, the data collected about time is discrete. Time stamps play a key role, and time has dimensions (e.g., hour, day, month) that interact. Finally, time has two forms—Universal Time (UTC), which is like geographic coordinates, and local time, which is like projected coordinates. He concluded that space-time reference frames and tools for moving data between them were needed.

The GeoDesign and spatiotemporal tools being developed will magnify the impact of GIS on society's understanding of the world that can inform human behavior to act in a more sustainable manner. As Paul Torrens, an associate professor in the School of Geographical Sciences at Arizona State University and director of its Geosimulation Research Laboratory, has observed, "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." The current integration of design and space-time into GIS processes and software represents a significant step in the ability of GIS to enable geographic knowledge.