ON THE PROFESSION

Public Cyber-Infrastructure for Spatial Analysis

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Spatial science is a fast-growing field that studies spatiotemporal aspects of people, places, and processes using information technologies. It encompasses technologies ranging from satellite imaging and geographic information systems (GIS) to spatial data and models of data derived from social networks and fieldwork. Key research agencies—including the National Science Foundation and National Institutes of Health in the United States—have targeted spatial science for dramatically increased funding. Scientific bodies, including the U.S. National Academies and the United Nations Educational, Scientific and Cultural Organization, herald spatial science as an integrative approach and a research topic of vital importance to a wide array of disciplines encompassing Latin Americanists. Importantly, these agencies point to a need for better spatial science infrastructure, including physical systems centered on computing and communication as well as scientific data standards for archiving, discovery, and dissemination.

This spatial science infrastructure takes many forms, but we describe two examples here. The first is Terra Populus (TerraPop), spatial data infrastructure designed to create new opportunities for understanding the relationship between population and the environment at scales ranging from the local to global <http://www.terrapop.org>. The second is U-Spatial, the University of Minnesota Spatial Sciences and Systems Infrastructure, which coordinates and supports spatial data, training, and research on campus <http://uspatial.umn.edu>. In addition to examining specifics of each project, we use these examples to examine some of the larger institutional and resource dimensions of large-scale spatial data infrastructure.

TerraPop

Terra Populus: A Global Population/Environment Data Network, is an ambitious project to create population-environment data that are both locally accurate and global in coverage. TerraPop will combine two centuries of census data from close to a hundred countries with global environmental data, including land cover, land use, and climate records. Beyond the goal of integrating this information into a common database, the team plans to disseminate the newly available data to researchers around the world. Many high-quality environmental and population data sets exist, but they are widely dispersed, have incompatible or inadequate documentation, and often include incompatible or incomplete spatial locational information. Newly available population data closely integrated with data on the environment will more clearly describe the unfolding transformation of human and ecological systems.

TerraPop aims to accomplish four specific tasks over the coming years:

- Collecting, preserving, integrating, and describing datasets that measure changes in the world's population and environment over the past two centuries.
- Developing tools and procedures to manage and disseminate the data collections. This work involves spatiotemporally harmonizing census data by addressing statistical and mathematical challenges of integrating large socioeconomic datasets.
- Carrying out education and outreach to engage the scientific community and the public and reach the broadest possible audience. This involves outreach at professional conferences, specialized workshops and training sessions, and an Internet presence.
- Establishing an organizational structure to ensure the long-term sustainability of the project, including development of an endowment fund and cross-institutional ties with leading data archives around the world. TerraPop is also a partner in the National Science Foundation's Sustainable Digital Data Preservation and Access Network (DataNet). The DataNet initiative aims to provide reliable digital preservation, access, integration, and analysis capabilities for science data over a decades-long timeline.

U-Spatial

Over five hundred researchers in over fifty departments at University of Minnesota (UMN) actively conduct spatial science research, and many more have expressed interest, yet the university has had no organized research infrastructure in this area until now. U-Spatial focuses on modest yet critical coordinated infrastructure improvements to enhance the university's spatial science activities. U-Spatial is a network of research nodes that enhances existing UMN research strengths, eliminates duplication and fragmentation of scientific resources, and provides a framework of data, equipment, expertise, and resources. These nodes provide the U-Spatial infrastructure via four infrastructure cores:

Central Core. The central core provides general assistance and resource coordination. Services include walk-in help desks and online services to provide general assistance with analysis and simple mapping. Assistants will also direct advanced problems to secondary nodes and

experts. The central core also provides training via a program of short workshops that cover spatial science basics all the way through to advanced courses tailored to specific domains (e.g., public health or humanities). For example, we offer a GIS 101 course, a free one-day workshop introducing participants to GIS fundamentals. Last year, almost 150 people participated in the workshops, and the sessions remain oversubscribed. Many GIS 101 participants learn the basic skills needed to use GIS in their research, while others contact the help desk for more specific training.

Data Core. A recent special issue of *Science* titled "Dealing with Data" (February 11, 2011) argues that we must better deal with the "deluge" of huge and complex data sets in the face of critical shortcomings in data archiving and discovery. These needs are writ large for spatial science research on campus. U-Spatial helps researchers archive their data and make it discoverable and reusable by others. U-Spatial provides expertise in data management, archiving, and discovery services that greatly improve data reuse and citation capabilities. Access to spatial data is being addressed by two groups. The first group is piloting a web-based system to make spatial data easy to discover and access, while the second is focusing on the long-term archiving and preservation of data.

Imaging Core. Remote imaging, or digital images of the earth made from planes and satellites, is critical to research domains ranging from deforestation measurement to urban growth analysis. Given the vast amount of data involved and the expertise and systems necessary for converting raw data into a format suitable for scientific analysis, researchers cannot currently take full advantage of these resources. U-Spatial is making remote imaging fully accessible to UMN researchers, which involves managing data from multiple-sensor platforms and offering expert help on image collection and analysis.

Analysis Core. Research on complex, pressing problems such as climate variability and rapid social change requires advanced spatial analysis. One part of the core is developing modeling infrastructure, including a library of open-source models and expertise for applying it to various domains. U-Spatial is also developing specific datasets which are currently in great demand (e.g., a spatially enabled public health database that is tied to census data). Another focus of U-Spatial is on geodesign, the application of technology to allow decision makers to collaboratively construct and evaluate landscape plans using spatiotemporal modeling and three-dimensional visualization. Geodesign nodes will each host touch tables and multiple display facilities that will be synchronously interactive. The final focus is mapping, where U-Spatial is building on successful GIS and web-mapping programs that provide data and expertise to researchers working on scientific problems in Minnesota and elsewhere.

Outlook

Spatial science infrastructure is necessary. For example, we identified the need for U-Spatial infrastructure through a comprehensive assessment of existing capacity, including surveys, a strategic assessment in which we interviewed dozens of stakeholders, and a nationwide comparison where we interviewed leaders and users of similar spatial science infrastructure at a dozen top research universities. We surveyed faculty and students in a single academic unit, for example, and over two hundred respondents across the arts, humanities, and social sciences wanted to use spatial science in their work, but only a handful had the requisite support and available expertise. Desired projects included representing shifting perception of Latino immigrants over time to quantitative sociological studies of racial inequality in cities. Many similar issues held true for TerraPop, where literally hundreds of researchers around the globe have started to use the underlying harmonized census data and have expressed great interest in linking it to environmental data. TerraPop and U-Spatial provide just two examples of the larger needs for spatial science and data.

Spatial data infrastructure is complex and therefore expensive. While the accessing of spatial data—such as free satellite data via the Internet or the global reach of Google Maps—is ncreasingly easy and inexpensive, using the data and their associated methods and theory usually necessitates deeper infrastructure. U-Spatial is funded by $2.5 million over 2012–2017, two-thirds of which is from the University of Minnesota's Infrastructure Investment Initiative, with the remaining third contributed by seven colleges, three large research centers, and three central administrative bodies including libraries and information technology. It involves dozens of staff, faculty, and students. TerraPop is similarly complicated. It was awarded a five-year, $8 million grant from the U.S. National Science Foundation's Office of Cyberinfrastructure, which requires cooperation among many institutions, given the complexity and depth of the issues involved. The Minnesota Population Center leads the effort with support from the Institute on the Environment, the University of Minnesota Libraries, and faculty from the College of Liberal Arts and the College of

Science and Engineering. Additional partners include the Center for International Earth Science Information Network at Columbia University (CIESIN), a leading research and data center focused on human-environment interactions, and the Inter-University Consortium for Political and Social Research (ICPSR) at the University of Michigan, the world's largest social science data archive. The Minnesota Population Center is home to the largest collection of census data in the world, while the Institute on the Environment has one of the most extensive databases of global land use in the country.

Learn more at <uspatial.umn.edu and www.terrapop.org>. ■

DEBATES

Evolving Practices of Citizenship amid Institutional Reform

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The *Debates* section in this issue explores the ways in which political institutional reform has altered the manner in which citizenship is expressed and practiced.

The third wave of democratization in Latin America has been accompanied by reforms in representative as well as participatory institutions. Countries have followed diverse paths. In some cases, pacts among the elites materialized during processes of transition. In other cases, bottom-up processes of social mobilization allowed for radical transformations of the political systems—usually through the approval of new constitutions. In some cases, sequential modest reforms have allowed political actors to adapt institutions to changing environments.

In all these processes, three main issues are at stake. First, reformers have scrutinized representative institutions, such as electoral systems, and the effectiveness with which they channel and aggregate citizen interests. Second, political and social actors have addressed the question of empowering citizens within the decision-making process. Debates on the promotion of direct mechanisms of citizen participation are central at local and national levels and reflect bottom-up approaches toward democratic politics. Finally, in several countries organized indigenous groups have advanced a political agenda concerning self-determination and cultural and political recognition and autonomy. Thus, institutional shifts are reflecting new democratic challenges in a highly dynamic political landscape. ■