GISCIENCE GRAND CHALLENGES

How can research and technology in this field address big-picture problems?

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To a GIS practitioner, the distinction between GIS and GIScience may be difficult to get a handle on. *Geographic information science* is a term coined in a 1992 paper in the *International Journal of Geographic Information Systems* by University of California, Santa Barbara, professor Michael Goodchild. The idea actually came from his 1990 keynote speech called Spatial Information Science, delivered at the 4th International Symposium on Spatial Data Handling in Zurich, Switzerland.

I attended that symposium, and I recall some skepticism in the audience: were we witnessing an attempt to turn something methodological into a science merely to build our credibility in the eyes of funding agencies? Some remarked that fields that find the need to add the qualifier "science" to their name (political science, computer science) are by definition not legitimate sciences. But semantics aside, Goodchild's basic argument that "GIS needs a strong scientific and intellectual component" (or else the technology might be short-lived) was generally accepted. The GIScience term stuck, and almost two decades later, many university graduate programs now focus on GIScience rather than on GIS.

University at Buffalo professor David Mark defined GIScience in 2003 as "the development and use of theories, methods, technology, and data for understanding geographic processes, relationships, and patterns." Practitioners can think of GIScience as the key foundational ideas (which become algorithms and then code) that make GIS software tick. In many cases, GIS software has become a test bed or sandbox for validating GIScience ideas.

Grand Challenges

Grand challenges play a key part in advancing science and engineering, especially in the most highly developed economies. These challenges have included races to reach the New World, set foot on the moon, build the highest skyscraper, or decode the human genome. Most scientific societies today publish manifestos outlining what they consider to be the grand challenges of their particular field of interest. Why should GIScience be any different?

At the recent Association of American Geographers (AAG) annual meeting in Washington, D.C., a special session was organized in conjunction with the University Consortium for Geographic Information Science (UCGIS) to address some of the grand challenges for GIScience. According to the organizers, a *grand challenge* is defined as follows:

"Grand challenges are not merely routine research questions or research priorities but questions and directives that (1) are extremely hard to do, yet are doable; (2) produce outcomes potentially affecting millions, if not hundreds of millions of people; (3) require multiple research projects across many subdisciplines in order to be satisfactorily addressed; (4) consist of well-defined metrics such that, through creativity and commitment, can be realistically met and one knows the end has been reached; (5) capture the popular imagination, and thus political support."

The session was led by professor Dawn Wright of Oregon State University and included invited speakers from diverse sectors. As was to be expected, not everyone agreed on the same top five challenges, but it is interesting to review the challenges that were suggested.

Tim Nyerges of the University of Washington and president of UCGIS, outlined previous iterations of UCGIS projects aimed at identifying grand challenges. In the latest iteration, centered on a GIScience Knowledge Web, he identified geocyber infrastructures, spatio-temporal languages to describe dynamic processes, and support for distributing geographic decision making.

May Yuan, professor at the University of Oklahoma and incoming president of UCGIS, strongly concurred with the challenge theme, which she labeled as spatiotemporal models, languages, and ordering. These are different ways to look at representing and analyzing dynamic processes in and across space.

Peggy Agouris of George Mason University reported on findings of the National Science Foundation Workshop on Geospatial & Geotemporal Informatics, and her grand challenge list reflected that focus. To the common spatiotemporal emphasis she added adaptive, multimodal geosensor networks and related analysis of dynamic processes and event-driven modeling and analysis.

Jerry Johnston, the geospatial information officer of the U.S. Environmental Protection Agency, suggested three challenges: radically improved user interfaces (beyond maps) for participatory GIS; a digital earth that incorporates citizens as sensors; and the geospatial semantic Web, including open linked data in the sense promoted by Tim Berners-Lee.

Ted Cope of the National Geospatial-Intelligence Agency made an entertaining presentation that, surprisingly, included human geography as one of the challenges. By that, he meant that his agency and others related are striving to learn more about the human context (unseen from space imagery) of geographic areas where they intervene around the world. This is indeed an interesting challenge for GIScience, because it touches on the largely nonquantitative, not easily automated fields of history; sociology; anthropology; language arts; psychology; and, of course, geography. Semantics and uncertainty are also important research challenges for the geospatial intelligence (GEOINT) community in general.

In a publication for the *Journal of Spatial Information Sciences,* entirely unconnected to the AAG session but published at roughly the same time, Goodchild reviewed progress during the first 20 years of GIScience. The article concluded with a look at the future of GIScience, and the short list included

- Knowing where everything is at all times (GPS, RFID, etc.)
- Role of the citizen (neogeography, volunteered geographic information, or VGI)
- A technology of dynamics (real-time monitoring and analysis)
- The third, fourth, and fifth dimensions (including time and uncertainty)
- Challenge of education (basic GI concepts for public consumption)

The coincidence is uncanny, so much so that we can be fairly confident that GIScience research in the coming years will focus, in part, on these areas.

For a third perspective on GIScience grand challenges, let's look at the U.S. National Research Council (NRC) March 2010 report entitled *Understanding the Changing Planet: Strategic Directions for the Geographical Sciences.* The report focuses on societal benefit areas, or what we might call big-picture problem areas, similar to the United Nations Millennium Development Goals. The NRC-commissioned panel that drafted the report summarized the goals for the coming decade in terms of 11 strategic questions that were grouped in four areas:

How to understand and respond to environmental change	1. How are we changing the physical environment of earth's surface? 2. How can we best preserve biological diversity and protect endangered ecosystems? 3. How are climate and other environmental changes affecting the vulnerabilities of coupled human-environment systems?
How to promote sustainability	4. Where and how will 10 billion people live? 5. How will we sustainably feed everyone in the coming decade and beyond? 6. How does where we live affect our health?
How to recognize and cope with the rapid spatial reorganization of the economy and society	7. How is the movement of people, goods, and ideas changing the world? 8. How is economic globalization affecting inequality? 9. How are geopolitical shifts influencing peace and stability?
How to leverage technological change for the benefit of society and environment	10. How might we better observe, analyze, and visualize a changing world? 11. What are the societal implications of citizen mapping and mapping citizens?

Eleven challenges from the U.S. National Research Council (NRC) report *Understanding the Changing Planet: Strategic Directions for the Geographical Sciences*

Strategic Directions for the Geographical Sciences

It is interesting to consider these big-picture problems and the extent to which GIS technology and GIScience research can contribute to viable, tractable solutions.

Esri has been active in supporting GIScience initiatives, looking at these and related areas. In February 2010, the first Redlands GIS Week was celebrated at Esri's headquarters and brought 150 researchers together to discuss advances in space-time modeling and analysis. The second Redlands GIS Week, in February 2011, will focus on the impact of collecting and processing VGI especially for real-time and emergency management scenarios. Esri organizes a special GIScience track at the annual User Conference in San Diego. Papers accepted for that track are published in the peer-reviewed journal *Transactions in GIS.* And Esri has for more than a decade sponsored and participated in the Association of Geographic Information Laboratories in Europe (AGILE) and GIScience international conference series, including GIScience 2010, right back in Zurich.

About the Author

Dr. Michael Gould studied GIScience at the National Center for Geographic Information and Analysis, University at Buffalo, then taught in Spain and was principal investigator on several European Union-funded research projects between 1991 and 2008. He was a member and the chair of the management board of AGILE and cofounder of the Vespucci Institute for GIScience and related summer schools. He now directs the Esri education industry team and oversees global education projects and strategy.