GEOGRAPHICAL INFORMATION SCIENCE FIFTEEN YEARS LATER

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INTRODUCTION

In early 1990 Kurt Brassel asked me if I would be willing to give a keynote at the Fourth International Symposium on Spatial Data Handling (SDH), which was being planned for July of that year. I accepted, but it was not until late March that I gave serious thought to what I would say. At the time the US National Center for Geographic Information and Analysis (NCGIA) was eighteen months old, with a mandate from the National Science Foundation to pursue basic research on geographic information systems (GIS) and to promote the use of GIS within the sciences. That same year Terry Jordan, President of the Association of American Geographers, had called GIS "non-intellectual expertise", reflecting a growing sentiment within many parts of the discipline that saw GIS as a matter of pushing the right buttons, and wondere why it was worth any more attention from geographers than, say, the hand calculator. The SDH series had evolved as the premier international meeting of the GIS research community, and it seemed to me appropriate that my keynote should focus on science, and on what it would take to bring respect for the field from the broader academy, both inside and outside geography. David Simonett, my NCGIA co-director, had argued for many years that remote sensing needed a strong emphasis on science and theory to be regarded as anything more than a bag of tricks, and was adamant that the GIS community needed to build along similar lines; and it annoyed me that the premier international meeting of the field had a title that suggested that we were driven merely by the difficulty of "handling" a particular type of information – that we were merely "the United Parcel Service of GIS". I tried to capture some of these ideas in a conference proceedings paper, which I wrote one afternoon while in St Lucia working on *Geographical Information Systems: Principles and Applications* with David Rhind and David Maguire (Maguire, Goodchild, and Rhind, 1991).

The paper seemed to strike a chord with the audience, and I repeated the message with some embellishments at the EGIS (European GIS) conference early in 1991. The two conference papers were eventually combined into a single paper that appeared in *IJGIS* in 1992. To quote:

> "The GIS community has come a long way in the past decade. Major research and training programs have been established in a number of countries, new applications have been found, new products have appeared from an industry which continues to expand at a spectacular rate, dramatic improvement continues in the capabilities of platforms, and new and significant datasets have become available. It is tempting to say that GIS research, and the meetings at which GIS

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> research is featured, are simply a part of this much larger enthusiasm and excitement, *but there ought to be more to it than that*." (Goodchild, 1992; emphasis added).

In the paper I deliberately played on the GIS acronym, asking whether the "S" might not usefully stand for "science" rather than "systems", and in turn asking what such a science might encompass. Since then others have continued the word-play, suggesting that GIStudies might be a useful term for investigations into the social context and impacts of GIS, and that GIServices should denote any remotely invokable processing capability (Longley *et al.*, 2005).

Evidently the paper did not fully satisfy the need for a complete and lasting definition of the field. As the paper makes clear, my intent was to capture those aspects of GIS research that concerned questions of fundamental scientific significance, and that could drive a science that would eventually earn the respect of the academy – that would lead, for example, to election of GIS researchers to the US National Academy of Sciences or the UK's Royal Society (the field has been successful on both counts), or to the establishment of professorships in GIS in the most prestigious insitutions. I was also concerned that the field's questions be unique, and that there be internal coherence within it. I chose to define GIScience as "Research on the generic issues that surround the use of GIS technology, impede its succesful implementation, or emerge from an understanding of its potential capabilities"; Mark (2003) has provided an excellent history of the various efforts to clarify the definition of GIScience over the years. I also noted that GIScience might take two essentially distinct forms: research *about* GIS that would lead eventually to improvements in the technology; and research *with* GIS that would exploit the technology in the advancement of science. Both of these themes are clearly evident in the way the term GIScience is used today.

The concept of GIScience seems to have been adopted enthusiastically. Journals (including *IJGIS*) have been renamed, books have been published (*e.g.*, Bishop and Schroder, 2004; Cho, 2005; Duckham, Goodchild, and Worboys, 2003; McMaster and Usery, 2004; Raper, 2000), a major consortium of US universities has been established (the University Consortium for Geographic Information Science, www.ucgis.org), and specialist programs have appeared in academic institutions. The *systems versus science* issue has been revisited (Wright, Goodchild, and Proctor, 1997), and reports have been written calling for the establishment of major programs of research funding (Mark, 1999). Efforts have been made to define the *grand challenges* of the field (Longley *et al.*, 2005; Mark, 1999), and to identify its fundamental principles (Goodchild, 2003). Problems of nomenclature will always be with us, of course, and one can find numerous terms in use that are either fully or partially equivalent: geoinformation science, spatial science, spatial information engineering, geomatics, geoinformatics, and geospatial information science to name a few. But despite the well-known caution "Every field that needs to call itself a science probably isn't", after 15 years there seems every reason to believe that GIScience is a genuine, challenging, and fruitful area for scientific research with its own unique scientific questions and discoveries.

REASSESSMENT: WHAT DID I MISS?

In the third section of the paper, titled “The Content of GIScience”, I attempted to outline what seemed to me at the time to be the major divisions of the field. They make interesting reading 15 years on:

- Data collection and measurement;
- Data capture;
- Spatial statistics;
- Data models and theories of spatial data;
- Data structures, algorithms, and processes;
- Display;
- Analytic tools; and
- Institutional, managerial, and ethical issues.

While it bears strong resemblance to early statements of the NCGIA research agenda (NCGIA, 1989), it clearly misses many of the subsequent developments of the field. “Data models and theories of spatial data” is a poor apology for what subsequently became the basis for the COSIT (Conference On Spatial Information Theory) conference series, drawing heavily on work in linguistics and cognitive science, and crystallizing around the term *ontology*. The emphasis on the *tools* of analysis in the penultimate bullet, rather than on analysis itself, missed virtually all of the key developments in analytic methods of the past fifteen years. “Display” scarcely credits or anticipates what has evolved into the highly productive field of geovisualization, while “Spatial statistics” does little to convey the importance of uncertainty, which is now one of the most conspicuous specialties of GIScience, or the degree to which it has also drawn on the field of geostatistics. Comparison with the 2002 research agenda of UCGIS (www.ucgis.org) simply reinforces these observations.

Above all, however, I missed the impact of the Internet, and the way in which it has massively impacted the GIScience research agenda since 1993. From the perspective of 1990 GIS was akin to a desktop *butler*, an intelligent machine for performing what its master or mistress found too tedious, imprecise, costly, or complex to do by hand. With the Internet, however, GIS became primarily a *medium*, a means of communicating one person’s knowledge of the planet’s surface and near-surface to others. Suddenly the sharing and dissemination of data became the subject of enormous investment, in digital libraries, data warehouses, metadata standards, and geo-portals (Longley and Maguire, 2005). The entire field of GIServices was unanticipated in 1990, as was the challenging research topic of interoperability (Goodchild *et al.*, 1999), with its concern for differences of syntax and semantics. Indeed, one wonders what a GIScientist of 1990 would have made of the term *spatial web*.

This new paradigm of GIS has been recognized in numerous ways. In the UCGIS research agenda of 2002 it underlies several topics: the Long-Term Research Challenges of Spatial Ontologies, Spatial Data Acquisition and Integration, Distributed Computing, and The Future of the Spatial Information Infrastructure; and the Short-Term Research

Priorities of the Geospatial Semantic Web, Geospatial Data Fusion, Institutional Aspects of Spatial Data Infrastructures, Geographic Information Partnering, and Pervasive Computing (www.ucgis.org). It has been described in many books (*e.g.*, Peng and Zhou, 2003; Plewe, 1997), and in a growing journal literature. As the editors noted in the comments that introduced the second edition of *Geographical Information Systems* (Longley *et al.*, 1999), the most obvious failing of the first edition was its complete failure to anticipate the impact of the Internet and the Web. We continued to see a GIS as something that existed *in one place*, long after early visionaries had argued that computers would inevitably be networked and their tasks distributed. In hindsight, the case for distributing a technology that deals with the distribution of activities and phenomena over the Earth's surface seems particularly obvious and compelling.

DIRECTIONS IN GISCIENCE

As I have argued, the GIScience of 2005 is very different from the one that prompted my keynote of 1990 – and there is every reason to expect that GIScience will continue to evolve and change in the coming years. Three topics seem particularly worthy of attention at this time.

First, there are strong arguments that the focus of GIScience needs to shift from representation and analysis of the *form* of the Earth's surface to a much stronger concern for the *processes* that define its dynamics (Goodchild, 2004). But while geographers have always been custodians of knowledge about form, arguably the custodians of process have been the substantive sciences of surficial geology, ecology, hydrology, epidemiology, demography, economics, *etc.* A concern for process is therefore likely to change the landscape of GIScience dramatically, requiring much closer interaction with these sciences. The notion of research *with* GIS takes on different meaning, requiring that GIS be redesigned to support the process models of the sciences, rather than generic and simplistic representations of form.

Second, the past year has seen an unprecedented series of developments in the ways in which the general public interacts with GIS. Nowhere is this more evident than in the case of Google Earth and its look-alikes (Microsoft's Virtual Earth, NASA's World Wind, *etc.*). Today, a child of ten can generate a fly-by using a simple user interface with no more than a few minutes of instruction, a task that would previously have required a year's exposure to commercial off-the-shelf GIS in a university course. We are moving rapidly from a *concert pianist* model of GIS as a tool confined to experts, to a *child of ten* model in which the power of GIS is available to all, the obvious concerns about powerful and complex technology in the hands of naïve users notwithstanding. Google's publication of KML has empowered a creative population of hackers that dwarfs the development staffs of the major GIS software vendors.

Third, it is clear that the knowledge accumulated by the discipline of GIScience is applicable to varying degrees in any space, and not limited to the space of the Earth's surface and near-surface. Much of the GIScience research agenda can be motivated equally well by other spaces, such as the three-dimensional space of the human brain, or

the one-dimensional space of the human genome. At the same time, advances made in the study of other spaces may be suitable sources of cross-fertilization in GIScience. Perhaps the next decade will see a much greater degree of interaction between GIScience and the sciences of other spaces, and much more productive collaboration.

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