Rethinking Spatial Science Education Programs

John P. WILSON and Michael F. GOODCHILD

Abstract

The growth of geographic information science as a field of study and tremendous gains afforded by technological advances have shifted the attention of educators to the various ways in which they might establish and nurture communities of GIS-savvy scholars. New cohorts of students will likely bring a much greater range of interests, skills, and experiences as well. Here, we explore some of the ways in which we might build a series of varied and effective pathways to support different learning outcomes and styles.

1 Introduction

The demand for graduates who are trained in spatial perspectives is strong and likely to grow in the years ahead driven by trends in and outside the academy. Inside, scholars are working to characterize the cognitive basis of spatial thinking (e.g. NEWCOMBE 2010), to specify and improve geospatial ontologies (e.g. CRUZ et al. 2007], to characterize the representation of place from multiple viewpoints (e.g. GIERYN 2000, HUBBARD et al. 2004), and to model the many human and environmental activities and events that vary across space and time (e.g. TORRENS 2012), among other topics. Beyond the academy, the U.S. Government has proposed a single geospatial enterprise to support all aspects of its work and the U.S. Department of Labor has proposed a Geospatial Technical Competency Model (DIBIASE et al. 2010) and a series of geospatial job titles. Geospatial professionals are spread throughout the public, private and not-for-profit work force at all levels. Increasing numbers are certified and there are frequent calls for individual programs to be accredited (as happens in other professional fields) (e.g. KEMP 2003). These developments are facilitated by continued work on interoperability spearheaded by the Open Geospatial Consortium (COWEN 2007), the development of spatial data infrastructures (MASSER 2005), and rapid spread of geospatial applications across local, enterprise, web and mobile computing platforms (WANG 2010).

However, this brief history tells only part of the story because a spatial "turn" has recently spread across the sciences. Hence, space has recently found new theoretical significance in ecology (TILMAN & KAREIVA 1997), and SCHOLTEN et al. (2009) have described the rapid spread of spatial thinking and GIS throughout the sciences. This is not unexpected, since the ability to reason with complex 3-dimensional structures and their Fourier transforms was clearly instrumental in Watson's and Crick's discovery of the structure of DNA, and the ability to draw inferences from spatial pattern has been critical in numerous breakthroughs in epidemiology, starting with Snow's 19th century work on cholera. The Association of Computing Machinery has recently formed a SIGSPATIAL Special Interest Group on "issues related to the acquisition, management, and processing of spatially-related in-

Jekel, T., Car, A., Strobl, J. & Griesebner, G. (Eds.) (2012): GI_Forum 2012: Geovizualisation, Society and Learning. © Herbert Wichmann Verlag, VDE VERLAG GMBH, Berlin/Offenbach. ISBN 978-3-87907-521-8.

formation" and two recent reviews (SHEKHAR & XIONG 2008, LIU & ÖZSU 2009) have highlighted some of the "hard" computing problems that still need to be solved.

The so-called spatial "turn" has influenced the social sciences and humanities as well. This paradigm shift has proceeded from the elemental recognition that all human action literally *takes place*, and that the spatial dimension of social interaction is of paramount importance for understanding all of the classic questions about the human condition (e.g. TUAN 1977, CASEY 1997). This transformation began in the 1970s, peaked in the 1990s, and has now spread so that every field in the social sciences and humanities is now fully engaged with the transformative impact of considering the spatial dimension of any research question (ETHINGTON 2007). Unlike other fields, the mode of analysis has been overwhelmingly qualitative and interpretive among humanities scholars and the GIS-based analyses that characterize the sciences are almost totally absent.

2 Current Needs

Herein then lies the challenge of building interdisciplinary spatial science programs. The systematic development of computational tools for handling spatial data began in the 1960s, and today GIS and software for image processing, pattern recognition, and scientific visualization are in widespread use throughout the academy, from the physical sciences to the humanities. Functions for the manipulation, analysis, and modeling of spatial data are now available in standard statistical and mathematical packages. The introduction of the Web in the early 1990s helped to make digital images readily sharable, and today's students are familiar with virtual spaces and the power of imaging through video games and digital movies. Pictures of Earth from space are now important tools in the earth and social sciences. However, the development of relevant theory and concepts, and the cultivating of spatial intelligence through education, has lagged far behind, and it is clear that a wide gap exists between the power and accessibility of tools on the one hand and the ability of researchers, students, and the general public to make effective and inspired use of them on the other.

The proliferation of GIS courses across geography, computer science, and other venues does little to seize the opportunity at hand – introductory classes in specific disciplines (i.e. archaeology, ecology, epidemiology, planning) never extend beyond basic concepts, those in geography often suffer because they rely on a relatively weak technology base, and those in computer science focus on the database issues and/or ways to augment the existing analytical and visualization tools with scant regard to what had been accomplished before the launch and widespread adoption of the Internet as a computing platform.

3 New Opportunities

The aforementioned assessment suggests that we have outgrown traditional models of education in the spatial sciences. New approaches for training future generations of students that start with a small number of introductory spatial classes and continue with a series of successively more advanced and focused spatial classes and seminars, some of which will provide "hands-on" training, are urgently needed. The following elements might be considered as a part of such plans:

- **New interdisciplinary courses,** such as separate course modules that focus on the technologies and core science. These might be taken together or separately and the technology modules might be aimed at specific disciplines and/or applications.
- **Supplemental programs of study,** such as an undergraduate minor or graduate certificate in spatial studies that complements traditional degree programs.
- **New interdisciplinary degree programs,** such as one in geodesign that draws on faculty expertise from architecture and planning as well the spatial sciences.

In addition, a strong case can be made for building these programs around the lingua franca of spatial analysis (Table 1). The various forms of spatial analysis constitute the crux of GIS (and the qualitative approaches that dominate the humanities), providing the means of adding value to spatial data and for turning these data into useful information. The literature is replete with examples illustrating how spatial analysis has helped to reveal and communicate things about human and environmental activities and events that might otherwise be invisible.

Table 1: Various classes of transformations, manipulations & methods that comprise spatial analysis (adapted from DE SMITH et al. 2000 & LONGLEY et al. 2010)

Class	Examples
Core concepts	Place, scale, location, distance, centrality, and area
Place-based analysis	Distance and directional analysis, geometrical processing, point pattern analysis, map algebra, and grid models
Spatial statistics	Exploratory spatial data analysis and spatial statistics, including spatial autocorrelation and spatial regression
Surface analysis	Surface form and flow analysis, gridding and interpolation methods, and visibility analysis
Network analysis	Shortest path calculation, traveling salesman problems, facility location and routing
Geocomputation	Agent-based modeling, artificial neural networks and evolutionary computing
Geovisualization	Spatial query, representation as process and meaning, and map (data) transformation

It is also the case that the world and our students are changing. DEMERS (2009, p. iii) wrote in the preface to the fourth edition of his introductory GIS textbook that it was aimed at "students who are comfortable with e-mail and text messaging, digital file formats (mp3, mp4, jpeg), computer games and visualizations, and a host of other technologies that did not exist ten years ago."

4 Conclusion

The emergence of geographic information science as a field of study and the tremendous gains afforded by technological advances have shifted the attention of educators to the various ways in which they might establish and nurture their community of GIS-savvy scholars. These individuals will likely bring a much greater diversity of interests, skills, and experiences than students did in the past and there is now an urgent need to build a series of varied and effective pathways to support these different learning goals, outcomes, and styles.

References

CASEY, E. S. (1997), The Fate of Place: A Philosophical History. Univ. of California Press, 495 p.

COWEN, D. J. (2007), The availability of geographic data: The current technical and institutional environment. In: WILSON, J. P. & FOTHERINGHAM, A. S. (Eds.), The Handbook of Geographic Information Science. Blackwell, 11-34.

CRUZ, I. F., SUNNA, W. G., MAKAR, N. & BATHALA, S. (2007), A visual tool for ontology alignment to enable geospatial interoperability. Journal of Visual Languages and Computing, 18, 230-254.

DE SMITH, M. J., GOODCHILD, M. F. & LONGLEY, P. A. (2000), Geospatial Analysis: A Comprehensive Guide to Principles, Techniques, and Software Tools. Winchelsea, 3rd edition.

DIBIASE, D. W., CORBIN, T., FOX, T., FRANCICA, J., GREEN, K., JACKSON, J., JEFFRIES, G., JONES, B., MENNIS, J., SCHUCKMAN, K., SMITH, C. & VAN SICKLE, J. (2010), The new Geospatial Technology Competency Model: Bringing workforce needs into focus. URISA Journal, 22 (2), 55-72.

ETHINGTON, P. J. (2007), Placing the past: 'Groundwork' for a spatial theory of history. Rethinking History, 11, 463-530.

GIERYN, T. F. (2000), A space for place in Sociology. Annual Reviews in Sociology 26: 463-496.

HUBBARD, P., KITCHEN, R. & VALENTINE, G. (2004), Key Thinkers of Space and Place. Sage, 353 p.

KEMP, K. K. (2003), Why GIS professional certification matters to us all. Transactions in GIS, 7, 159-163.

LONGLEY, P. A., GOODCHILD, M. F., MAGUIRE, D. J. & RHIND, D. W. (2010), Geographic Information Systems and Science. Wiley, 3rd edition, 560 p.

LIU, L. & ÖZSU, M. T. (Eds.) (2009), Encyclopedia of Database Systems. Springer, 3, 752 p.

MASSER, I. (2005), GIS Worlds: Creating Spatial Data Infrastructures. Esri Press, 312 p.

NEWCOMBE, N. S. (2010), Picture this: Increasing math and science learning by improving spatial thinking. American Educator, 34, 29-43.

SCHOLTEN, H. J., VAN DE VELDE, R., & VAN MANEN, N. (Eds.) (2009), Geospatial Technology and the Role of Location in Science. Springer, 322 p.

SHEKHAR, S. & XIONG H. (Eds.) (2008), Encyclopedia of GIS. Springer, 1, 370 p.

TILMAN, D. & KAREIVA, P. M. (1997), Spatial Ecology: The Role of Space in Population Dynamic and Interspecific Interactions. Princeton Univ. Press, 416 p.

TUAN, Y. F. (1977), Space and Place: The Perspective of Experience. Univ. of Minnesota Press, 235 p.

TORRENS, P. M. (2012), Moving agent-pedestrians through space and time. Annals of the Association of American Geographers, 102, 1-33.

WANG, S. (2010), A cyberGIS framework for the synthesis of cyberinfrastructure, GIS, and spatial analysis. Annals of the Association of American Geographers, 100, 535-557.