Geographic Categories: An Ontological Retrospective

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Since it is only five years since the publication of our paper, "Geographical categories: An ontological investigation" (Smith and Mark 2001), it seems somewhat strange to be making retrospective comments on the piece. Nevertheless, the field is moving quickly, and much has happened since the article appeared. A large number of papers have already cited the work, which suggests that there is a seam here that people find worthy of being mined.

In this short essay, we first review the paper and attempt to assess its significance from the perspective of our current work. We then put the paper in the context of our individual and joint works, which led up to it, and summarize our research trajectories since the paper appeared, pointing out what some of this reveals about spatial ontology in general. We conclude with some remarks on the future of ontological research in geographical information science.

Brief overview of our 2001 paper

The paper reported some of the main results of a series of experiments carried out in Buffalo and elsewhere between 1998 and 2001, and the inferences we were able to draw from those results concerning the ways normal human beings conceptualize their geographical environment. The idea for these experiments grew out of our general curiosity concerning the development of a theory of naïve or folk geography, itself reflecting our separate and collective interests in the work of Patrick Hayes and others on the topic of naïve or commonsense physics (Hayes, 1985; see also Smith and Casati, 1994 and Egenhofer and Mark, 1995).

How do nonexpert subjects conceptualize geospatial phenomena? To find a way of answering this question, we developed a series of simple questionnaire-style experiments in which we asked many hundreds of subjects to provide examples of geographical categories in response to a series of differently phrased elicitations. The results, we hypothesized, would yield an ontology of geographical categories — a catalog of the prime geospatial categories shared in common by human subjects independently of their exposure to scientific geography. To some extent this hypothesis was confirmed (for summaries, see our 1999 and 2001 papers presented at the Conference on Spatial Information Theory (COSIT) meetings (Mark et al., 1999, 2001).

Unfortunately, however, we very quickly discovered that the precise formulation of the elicitation question yielded significantly different catalogs of prime geospatial categories. Thus, if we combined the adjective *geographic* with the nouns *feature* or *object*, this yielded almost exclusively elements of the physical environment of geographical scale or size, such as *mountain*, *lake*, *river*. Even the words object and feature led systematically to somewhat different lists of examples. The phrase "thing that could be portrayed on a map," which a priori we had assumed would yield a roughly equivalent list of categories, produced instead examples of many geographical scale artefacts (*road*, *city*, etc.) and fiat objects (*state, country*, etc.: see Smith 2001), alongside the physical feature types elicited overwhelmingly by the *geographic feature* and *geographic object* triggers.

Interestingly, our data also suggested that there is considerable mismatch between the meanings assigned to the terms *geography* and *geographic* by geographic scholars and by ordinary subjects, so that there is a sense in which geographic scholars are not in fact studying geographical phenomenas, as such phenomena are conceptualized by naïve subjects. The data suggest, rather, a special role in determining the subject matter of scientific geography precisely for the concept of *thing can be portrayed on a map* — a result we believe to be worthy of further investigation.

Where we came from

Before writing the *IJGIS* article, we had been collaborating on GIScience research for several years. We met through a meeting of the Buffalo Cognitive Science Center, where Darren Longo, one of Smith's students, presented a paper on Mark's work on cognitive topology of spatial relations such as *across*, itself based on experimental work on human subjects' judgments concerning interrelations between roads intersecting parks in simple sketch maps. The COSIT meetings, and our common association with Andrew Frank in Vienna, played an important role in our research convergence. Mark's first published work on geographic categories was presented at the inaugural COSIT meeting on Elba, Italy, in 1993 (Mark, 1993), and Smith's first publication in the GIS-related literature was at the second COSIT meeting in 1995 in Semmering, Austria. Both papers have been moderately influential — according to Science Citations Index, Mark-1993 has been cited 16 times, and Smith-1995 almost double that (31 citations). Smith's work on fiat objects presented in Semmering was also incorporated into the IEEE Standard Upper Ontology, and formed one starting point of the theory of granular partitions, which Smith then developed in collaboration with Berit Brogaard, Thomas Bittner, and Pierre Grenon (Smith and Brogaard, 2002; Bittner and Smith, 2003; Grenon and Smith, 2004).

Our paper at the 1998 Spatial Data Handling meeting (Smith and Mark, 1998, 1999) laid out some of the basic principles and issues for ontology of the geographic domain, and led to U.S. National Science Foundation (NSF) support for the work beginning in July 1999 (Mark and Smith, 1999). The goal of the NSF project was to develop a formal ontology for geographic entities and categories, based on rigorous empirical research using human subjects. Parallel studies were conducted in several languages and regions, so the resulting ontology is at least to some degree multilingual. We still have much data collected during the original experiments, including data on how beliefs about geographical categories are expressed in a variety of different languages, which we would be happy to make available to researchers who are interested in going further along this trajectory.[2]

Developments since 2001: Smith

In the period immediately following the publication of our *IJGIS* paper, we co-authored additional papers on the more specific issue of the relationship between fieldlike structures captured, for example, in digital elevation models, and those geographic features captured in the lexicon of normal human subjects — the issue of the quantitative-qualitative divide (Smith and Mark, 2003; Mark and Smith, 2004). These papers highlighted the subtle and complicated relationship between the objective reality of the shape of the Earth's crust, and the features that people reason and communicate about in natural language. The World Wide Web is still highly oriented toward content presented as words in natural language, making field-to-feature conversion an important link in connecting geographic information to the Web. Analogous work at the interface between qualitative and quantitative geospatial data and information is also illustrated in other domains, for example in the field of military and intelligence-related information fusion. We both participated in a successful effort to have ontology adopted by the University Consortium for Geographic Information Science (UCGIS) as one of about 14 high-priority research topics for geographic information science in the United States (Mark et al., 2004). Ontology remains a hot topic in information science in general, and geographical information science in particular, and the 2001 special issue of *IJGIS* that included our paper was a key step in the promotion and legitimization of the topic within GIScience.

Since the publication of the paper, Smith has broadened his ontological purview to encompass spatiotemporal entities in all domains, presenting in particular the SNAP and SPAN ontology (Grenon and Smith, 2004), which is an attempt to do justice both to the process-oriented view, which sees the world as a constellation of four-dimensional entities, and the object-oriented view, which sees the world as comprised of continuant entities that endure identically through time. Smith has also directed much attention to the medical domain. In his 2005 COSIT paper, written with colleagues from the domain of biomedical informatics (Smith et al., 2005), he compares the achievements in qualitative and quantitative spatial ontology achieved in the domain of human anatomy with those achieved to date in GIScience. The most impressive achievement in spatial information science on the anatomical side thus far is the Foundational Model of Anatomy (FMA), a map of the human body conceived in ontological terms. Like maps of other sorts, including the maplike representations we find in familiar anatomical atlases, it is a representation of a certain portion of spatial reality as it exists at a certain (idealized) instant of time.

[2] One of the largest data sets, for English, is available on the Web at http://www.geog.buffalo.edu/ncgia/ontology/.

But unlike other maps, the FMA comes in the form of a sophisticated ontology of its object-domain, comprising some 1.5 million statements of anatomical relations among some 70,000 anatomical kinds. It is further distinguished from other maps in that it represents not some specific concrete portion of spatial reality (say, the Bay of Biscay), but rather a generalized or idealized spatial reality associated with a generalized or idealized human being at some generalized or idealized instant in time. Biomedicine provides a rich domain for such idealized qualitative representations of spatial structures, but it offers much more impoverished resources for describing individual instances. This is because your heart, for example, is constantly changing its shape, size, and location (Pilgram et al., 2004). The surface of the earth, on the other hand, provides a relatively impoverished domain for qualitative ontological representations, but much richer possibilities for the gathering of precise, quantitative instance data, by virtue of the fact that changes of shape, size, and location of the objects at or on the surface of the earth are, at least so long as we restrict ourselves to objects of geographic scale and to changes detectable through perception, relatively limited. Another difference between the anatomical and the geographical domain turns on the different role of fiat objects within each. Thus, for example, regions on the surface of the body delimited by fiat play a relatively insignificant role in Western anatomical science, but a central role in traditional Chinese medicine. Fiat demarcations on the surface of the Earth play a central role in the Western understanding of nations and sovereignty in the era since the Treaty of Westphalia, but a relatively insignificant role in the geopolitical ontology of Islam.

Developments since 2001: Mark

Mark's follow-up to the 2001 paper has gone in a quite different direction, focusing on in-depth examinations of definitions of geospatial feature types in other cultures and languages. Mark had been intrigued by the issue of whether spatial cognition was universal to all people, or whether there were significant cultural differences that should influence GIS design, but he had failed to come up with firm evidence either way. A sabbatical in 2002 was spent partly at the Max Planck Institute for Psycholinguistics in Nijmegen, and partly in western Australia. Through Andrew Turk's relationships with an indigenous community in Australia, Mark was finally able to dig into cultural differences in geospatial concepts deeply enough to reveal actual differences (Mark and Turk, 2003). This led in turn to research collaboration with David Stea, including another NSF grant (Mark and Stea, 2004) to compare landscape categories among several arid-lands peoples. Work in collaboration with Stea, Turk, and indigenous collaborators is already underway with the Yindjibarndi in Australia and with the Navajo in New Mexico and Arizona. Why have these studies found cultural differences in geospatial categories, when earlier researchers did not find them for spatial relations? At this point answers to this question are still in the realm of speculation, but it is plausible to hypothesize that spatial relations are more robustly hardwired into human perception, whereas categories for geographic entities are much less determined by basic cognitive factors. Most languages have a relatively small number of spatial relation terms, represented by closed-class

grammatical elements such as prepositions in English. Entity categories, on the other hand, are typically encoded in languages by nouns, the most open, extensible class of words. More research is needed, including research into cross-cultural differences in conceptualizations of spatial entity and relation categories, before definitive answers will be available. But if the proposed hypothesis turns out to be correct, the implication is that GIS software may be relatively easy to adapt to other languages and cultures, whereas spatial data infrastructures will need to pay specific attention to multilingual aspects of semantics and categorization.

Concluding comments

Ontology remains an important topic in GIScience, and can be expected to continue to be so for some time. Considerable interest is currently being exhibited in ontology above all by a number of federal government organizations, for example in the context of the development of the Federal Enterprise Architecture Reference Model Ontology. At a meeting in Buffalo in October 2005 there was inaugurated the National Center for Ontological Research, a consortium of government, industry, and academic partners dedicated to raising the standards of ontological research through application of the empirical scientific method. Informal comparisons of spatial ontologies for the geographical and anatomical domains suggest that even for the single domain of spatially extended entities, major differences among ontologies will have to be accepted as the order of the day, and this all the more so if cultural variance must be taken into account.

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20 Extending GIS-Based Visual Analysis: The Concept of Visualscapes

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Abstract. A Geographical Information System (GIS) is used to retrieve and explore the spatial properties of the visual structure inherent in space. The first section of the article aims to gather, compare and contrast existing approaches used to study visual space and found in disciplines such as landscape architecture, urbanism, geography and landscape archaeology. The concept of a *visualscape* is introduced in the following section as a tentative unifying concept to describe all possible ways in which the structure of visual space may be defined, broken down and represented within GIS independently of the context in which it is applied. Previous visibility studies in GIS are reviewed and further explored under this new concept. The last section presents the derivation of new visual parameters and introduces a new data structure (i.e., a vector field) to describe the *visual exposure* of a terrain.

1 Introduction

This paper describes the use of GIS to study human visual space. To date, the use of GIS to explore human space, i.e., as encountered by an individual, has been very limited. This is partly due to the fact that most GIS operations are based on a traditional geographical view of space which is essentially two-dimensional with a fixed and external frame of reference. The absence of GIS procedures that consider terrain and built environment representations together is a clear indication, among others, of these limitations. Hence, traditional GIS operations are inadequate for developing models of human–space interaction, particularly human perception, whenever a mobile frame of reference is considered. Though some attempts exist to relate GIS with cognition and perception, these have mostly concentrated on landscape preference (Baldwin *et al.* 1996, Germino *et al.* 2001). Ultimately, the design of new GIS routines, and/or the development of new spatial tools that will accommodate human and other factors, will become necessary if cognitive and perceptual factors are to be linked with spatial information. In the meantime, existing GIS can be used to illustrate the necessity and potential of these types of analyses.

The idea that any spatial configuration structures human visual space by virtue of its distribution and geometry, and that such structure can be described spatially