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Geographic Information Science: new geovisualization technologies – emerging questions and linkages with GIScience research

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Key words: data heterogeneity, GIScience, interactive geovisualization technologies, neogeography, qualitative spatial knowledge, volunteered geographic information.

I Introduction

In the world of geospatial technologies, change is afoot. In the past five years, we have seen the emergence of a wide array of new technologies that enable an ever-expanding range of individuals and social groups to create and disseminate maps and spatial data. Online mapping platforms such as Google Maps and Google Earth, Microsoft's Virtual Earth, or Wikimapia allow users to add their own geographic information to web-based displays or modify the contributions of others. Using geotagging, geoblogging, and the continued proliferation of GPS-enabled devices, photographs, narrative text, and video clips may now be embedded with details about their geographic location. These developments have been referred to with a plethora of terms, including neogeography (Turner, 2006), web mapping (Plewe, 2007), volunteered geographic information (Goodchild, 2007b), ubiquitous cartography (Gartner *et al*., 2007), and wiki-mapping (Guptill, 2007).

Much like debates about the societal impacts of GIS did in the mid-1990s, geographers' discussions of these new geovisualization technologies are shifting from an early wave of heady claims (both 'pro' and 'con') toward an effort to articulate key research needs. I will use this series of annual reviews to discuss some of the questions raised in this emerging agenda, and to outline connections with other research in geography that might productively inform these questions. In this first paper, I review some of the questions raised in the nascent literature on new geovisualization technologies, and discuss areas of GIScience research that can productively inform a key dimension of this phenomenon: its capacity to alter the nature and content of digital spatial data. In the second review, I will examine the social and political production and impacts of these new technologies, reviewing research from sociotechnological studies of GIS. In the final review, I will consider how work on critical

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visual methodologies might inform research about and with these new geovisualization technologies. This tripartite approach responds to one of the central tenets of critical GIS, namely that spatial technologies are many things simultaneously. They are digital systems for storing and representing spatial information; they are complex arrays of social and political practices; and they are ways of knowing and making knowledge.

II Web 2.0 meets GIS: emerging questions and concerns

These new geovisualization technologies are perhaps best characterized as 'not-quite-GIS' assemblages of hardware, software, and functionalities. Wiki-mapping, geovisualization APIs, and geo-tagging share something in common with geographic information systems, in so far as they play a part in the digital storage, retrieval, and visualization of information based upon its geographic content (Gold, 2006; Sheppard, 2006). But from this point differences abound. Their hardware and software systems have originated more as 'public' technologies than 'expert' technologies. As Goodchild (2007a) notes, many rely heavily upon Web 2.0 approaches that enable users to produce and share their own information online. The mapping and other geographic information services they provide are often more open for user-specification than those of conventional GIS software. Many rely on application programming interfaces (APIs), code that users may incorporate or 'mash up' into their own program or service. From the outset, these technologies have been orientated toward supporting multimedia representations of spatial information, including text, photographs, sounds, and any other media that are embedded or tagged with locational details.

Early discussions about the significance and impacts of these new technologies center around their impacts on the forms and content of digital spatial data, who produces and shares these data, and the purposes for which these data may be used. Some research illustrates how citizens and citizen groups are constructing new forms of activism, 'citizen science', or participatory democracy as they use these new technologies to collect, georeference, map, and share geographic information (Miller, 2006; Turner, 2006; Goodchild, 2007a; 2007b; Gouveia and Fonseca, 2008; Tulloch, 2008). In a familiar echo of debates about the empowerment and disempowerment potential of conventional GIS, other scholars suggest that these technologies simultaneously constitute new forms of surveillance, exclusion, and erosions of privacy (Harvey, 2007; Obermeyer, 2007; Zook and Graham, 2007a; 2007b). Others suggest that the growing ubiquity of geo-enabled devices and the 'crowd sourcing' of spatial information supported by platforms like Google Maps fuels exponential growth in digital data, and growing availability of data about everyday phenomena that have never been available digitally, nor from so many people and places (Miller, 2006; Gartner *et al*., 2007; Goodchild, 2007a; 2007b; Guptill, 2007; Williams, 2007). This anticipated shift in the nature and content of geospatial data has motivated some researchers to question whether existing spatial data models, analytical operations, search and retrieval techniques, or practices for assessing and promoting data quality will be appropriate (Goodchild, 2007a; 2007b; Gould, 2007; Craglia, 2007; Maguire, 2007; Mummidi and Krumm, 2008; Sui, 2008; Bishr and Mantelas, 2008).

These questions about the capacity of existing GIScience concepts and practices to handle the data created with these new technologies are particularly prescient. Given the diversity of sources from which they will flow, these data are likely to be tremendously heterogeneous. Spatial data provided about everyday life and represented in multimedia forms may rely heavily upon qualitative spatial knowledge and everyday forms of spatial reasoning (eg, 'This photo was taken a few blocks away from the

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Museum of Modern Art'). The interactivity inherent in the user-modified content of these interfaces may well increase the already socially dynamic reproduction and modification of spatial information. As I will discuss in the following section, while the digital representation, analysis, and handling of such forms of information has proved challenging, several areas of GIScience research provide a rich resource of concepts and practices for doing so, and hence have much to offer research on new geovisualization technologies.

III Productive linkages with GIScience research

Much of the excitement about these new technologies has to do with the information they might be used to produce and a multitude of possible uses imagined for these data. Some predict that researchers, policy-makers, citizen groups, and private institutions might use information contributed by ordinary people for any number of purposes, including emergency response, mobilizing activist efforts, monitoring environmental change, filling gaps in existing spatial databases, or identifying and addressing needs and problems in urban neighborhoods (Miller, 2006; Beardon, 2007; Bell *et al.*, 2007; Goodchild, 2007a; Lewis, 2007; Williams, 2007; Gouveia and Fonseca, 2008). Any of these applications would likely necessitate integrating data offered by countless individuals into larger data sets, as well as the ability to query, retrieve, and analyze these data, all of which pose challenges with qualitative, heterogeneous, or shifting data. Researchers have long noted the difficulty of representing, manipulating, and analyzing such forms of spatial data in digital environments (Sheppard, 1995; Harvey and Tulloch, 2006; Matthews *et al.*, 2006). Nonetheless, several areas of GIScience research are grappling with these representational and analytical challenges, and here I will explore their potential contributions to research on new geovisualization technologies.

A key challenge in any efforts to work with spatial data generated with these new technologies will be its likely heterogeneity and the difficulties this poses for integrating individual data records or multiple data sets into larger collections. Heterogeneity is intrinsic to any efforts to represent 'real world' characteristics or human observations, because of the diverse categorization schemes and complex semantics that are applied in this 'representational moment' of data creation (Harvey and Chrisman, 1998; Schuurman, 2004). For example, one form of heterogeneity is exemplified in the information contributed to a Google Maps mashup that allows users to post information on bad neighbors (http://www.rottenneighbors.com). In these data, the attribute 'rotten' is used to categorize many different activities or conditions (noise, trash, perceived nosiness). As well, this attribute is applied to activities that some people might not categorize as 'rotten'. Obviously, there are innumerable social and political concerns about such a website, which will be far more concerning to some readers than the heterogeneity of the spatial data produced in the postings to it. I engage these considerations in future reviews. Other forms of heterogeneity arise when similar conditions or entities are represented with different attributes, or measured with divergent measurement systems. Harvey and Tulloch (2006) and Elwood (2008) suggest that data heterogeneity is increasing at an ever-faster pace, a trend that raises difficult questions at the moment of data use: How do we integrate multiple data sets if the same semantics are used differently in each? How do we assess the pervasiveness of some phenomenon if it is identified differently by different data producers?

GIScience has developed a rich array of approaches for grappling with these challenges. One approach is to standardize terms across multiple sources (Winter and Nittel, 2003). Others use the formal ontologies of different data sets (Bittner and Edwards, 2001; Fonseca *et al.*, 2002; Brodeur *et al.*, 2003;

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Tomai and Kavouras, 2005) or measures of the 'semantic distance' between different terms (Kokla and Kavouras, 2002; Duckham and Worboys, 2005; Ahlqvist and Ban, 2007) to make decisions about whether data may be combined, compared or exchanged. Most of these approaches are orientated toward automating data integration or standardization, perhaps a key practice given the exponentially growing volumes of spatial data that are being created with new geovisualization technologies. But, as Schuurman (2006) has noted, such approaches may not adequately respond to the ways that data are dynamic, modified through individual and institutional interactions and practices. This observation is trenchant in the context of spatial data created with new geovisualization technologies. A foundational characteristic of these technologies is their support for user interaction in producing information, something that will likely escalate such data modifications.

More useful may be those strategies that focus on enriching data with information that will help the user assess heterogeneity, as they make decisions about data integration, analysis, and application. Existing approaches of this sort rely on metadata, data dictionaries, or graphical representations to specify the semantics in a data set or provide contextual details on the creation of the data (Fabrikant and Buttenfield, 2001; Kuhn, 2001; Agarwal, 2005; Schuurman and Leszczynski, 2006). The data created with new geovisualization technologies are likely to present a vexing conundrum: unprecedented volumes of data *and* unprecedented levels of heterogeneity. In this situation, useful strategies for data integration and interoperability will likely require drawing upon several of the approaches discussed above. Especially promising are those strategies that seek context-dependent ways of working with heterogeneous data, guided by the notion that the precise meaning of different geospatial data categories differs significantly depending on context (Ahlqvist, 2004; Rodriguez and Egenhofer, 2004).

Another development anticipated in early discussions of new geovisualization technologies is a growing need to handle qualitative forms of spatial knowledge or everyday human expressions of spatial relationships. Geotagged photos, video, and text and the information shared through interactive geovisualization platforms often represents individuals' observations or interpretations of places experienced in everyday life, described in ordinary 'natural language' rather than the scripted terms of a geospatial database. I might post a photograph of my house with the spatial descriptor that it is 'near' Puget Sound, rather than providing latitude/longitude coordinates or an exact measured distance. Alternatively I might have exact coordinates, but wish to search a spatial database for other information that is 'near' my house. The spread of new geovisualization technologies is broadening the use of such qualitative locational information and everyday spatial logic as the basis for searching, sharing, and retrieving spatial data, requiring continued development of spatial data handling techniques that can cope with these forms of information.

Initially termed 'naïve geography', there is an extended body of research in GIScience that has sought to develop ways of handling qualitative forms of spatial reasoning (Egenhofer and Mark, 1995). One of the basic challenges in this arena is how the unstructured, shifting, and context-dependent spatial concepts of human cognition might be represented in a digital environment, where exact measurements or consistent mathematical techniques are more easily handled. Consider, for example, the difficulty of creating an algorithm that would retrieve objects in one layer that are deemed 'too close' to objects in another layer. Representing this spatial relationship in quantitative terms is dependent upon the context. 'Too close' to a burning building is a very different measurement than 'too close' to a burning match.

Some GIScience research on qualitative spatial expressions seeks to conceptualize

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how descriptions such as 'my house is near Puget Sound' might be broken down into component parts and relationships, as a precursor to representing that information in a digital environment (Xu, 2007). Others are developing ways to encode these relationships into spatial databases, using mathematical techniques (Yao and Thill, 2005; Dilo *et al*., 2007), or visualization techniques such as animations or 3D surfaces (Yao and Jiang, 2005) to represent natural language expressions of proximity. A third layer of work in this arena focuses on ways that everyday spatial language might be used for the search and retrieval of geographic information, whether from GIS-based spatial databases or the internet (Winter, 2004; Brincicombe and Li, 2006; Delboni *et al*., 2007; Weigand and Garcia, 2007). As with research on data integration, much of this work on handling qualitative spatial data has not been explicitly linked to new geovisualization technologies. Given the degree to which these technologies support the creation and exchange of qualitative spatial data, this research has a critical role to play.

Finally, another important contribution from GIScience research comes from efforts to incorporate spatial knowledge into digital environments in ways that more effectively represent it as social and dynamic. This consideration is at the forefront of new geovisualization technologies, given the extent to which many of them support users' ability to interactively create and modify information. The names and characteristics that individuals and groups assign to a single geographic location may differ depending on their experiences, priorities, and identities. Consider, for example, how a user-accessible mapping interface might allow one user to designate a feature in Australia as 'Uluru' (as it is called by Aboriginal groups), while another user might modify this label to 'Ayers Rock' (the name given by European settlers), and other users might make further modifications. Such renaming of a geographic feature is far more than just revision of a data record. The names themselves, as well as the acts of renaming, constitute shifting meanings associated with a location, in this instance referencing and negotiating colonial and postcolonial histories, identities and experiences. Users' modifications of digital data have the potential to be a richly informative source of insights about social and political negotiations of meaning, but only if we can discern and explore the data modifications constituted in this digital environment.

Much recent work on spatial data integration and collaborative GIS has grappled with precisely this question of how geospatial data and technologies might better incorporate the social complexity and dynamism of geographic knowledge (Koua *et al*., 2006; Brodaric, 2007; Dean, 2007; Hopfer and MacEachren, 2007). Researchers have developed representational methods intended to make shifts of meaning explicit in the digital environments of geospatial technologies, rather than implicit. In the context of collaborative GIS, for instance, Gahegan and Pike (2006) have developed a visualization tool that represents the modification of concepts in a spatial database as they are used in the process of collaboration. Their system creates a durable tracing of how concepts and meanings are modified as different users work with shared data. Schuurman and Leszczynski's (2006) ontology-based metadata uses the existing structures of metadata to record contextual information that can guide interpretations of data, an approach that might be adapted to record iterative revisions by multiple data creators/users. These models were not developed specifically with an eye toward new geovisualization technologies, but their focus upon how geospatial technologies might more robustly handle data as socially produced and transformed suggests that this arena may be a fruitful resource for research on new geovisualization technologies. These research areas both emphasize how people use knowledge, specifically how knowledge is modified and meanings altered through

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individual and social engagements with knowledge using geospatial technologies.

IV Conclusion

Wiki maps, geoblogs, interactive web-mapping platforms, and geotagging may be relatively new practices, but some of the challenges they present are closely linked to what Fisher (2007) articulates as key challenges of geographic information science, including representation, visualization, data handling, and intermediating between human spatial knowledge and its representation in digital environments. But a unique and challenging aspect of these new geospatial technologies is their close connection to the everyday: more ordinary people creating digital spatial data, and the rising potential to represent aspects of everyday life through geovisualization. Gilbert and Massucci (2005) argue that shaping geographic information technologies in ways that are responsive to everyday knowledge requires our most sophisticated GIScience knowledge, a claim that I have sought to further support in this review. Nascent research on new geovisualization technologies envisions potentially beneficial applications for the data they are used to create, while also highlighting the challenge of working with such heterogeneous, qualitative, dynamic forms of spatial data.

The very characteristics of these new data that are deemed so promising are at the same time difficult challenges in GIScience. Integrating heterogeneous data, representing qualitative spatial expressions, and incorporating the dynamic meanings of data as they are transformed in use are all extremely complicated in a digital environment. I have reviewed some of the areas of GIScience research that are engaging these issues, in order to highlight some specific practices that might productively inform ongoing research on new geovisualization technologies. Of course, there are far more questions we need to ask about the significance and impacts of these technologies and the practices they are used to support, well beyond the spatial data handling and representation concerns I have focused upon here. In future reviews, I will consider in more detail how researchers in geography are theorizing and investigating new geovisualization technologies as social and political practices, and assessing their epistemological and methodological significance.

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