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REVIEW ARTICLE

The convergence of GIS and social media: challenges for GIScience

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It is hard to believe that 10 years have passed since we wrote our guest editorial for IJGIS (Sui and Goodchild 2001). Using the nascent evidence that emerged in the late 1990s, we speculated back in 2001 that geographic information systems (GIS) were rapidly becoming part of the mass media. On the basis of the proposition of GIS as media, we were able to link GIScience with theories in media studies such as Marshall McLuhan's law of the media, which considers modern media as modifiable perceptive extensions of human thought (Sui and Goodchild 2003). Remarkable conceptual and technological advances in GIS have been made during the past 10 years. The goal of this review is to provide an update on the 'GIS as media' argument we made 10 years ago and to discuss the new challenges for GIScience posed by the growing convergence of GIS and social media.

Keywords: social media; GIS; Web GIS; data mining

This paper is structured as follows. The first section provides an update on our original thesis on 'GIS as media', especially in the context of recent growth of Web-based GIS, the GeoWeb, and volunteered geographic information (VGI). The second section discusses the idea of 'media as GIS', in the context of growing applications of GIS in journalism and the recent phenomenal growth of social media, especially location-based social networking. The third section discusses the implications of an accelerated convergence of GIS and social media for GIScience research in the near future. The fourth section provides the summary and conclusions.

1. Geographic information systems as (social) media: online mapping sites are increasingly social

As geographic information systems (GIS) moved from earlier models of running on stand-alone desktop computers or workstations to the World Wide Web, their primary function as a tool for sharing and communicating our knowledge about the Earth's surface became more obvious. Currently, we have thousands of websites offering a variety of mapping or geospatial services. Indeed, the launching of online mapping tools such as Google Earth, Microsoft's Virtual Earth/Bing Maps, and NASA's World Wind validated our speculation

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(Ball 2005, Sui 2005). That GIS have also increasingly been recognized as media by software-tool developers and vendors is indicated by the names they choose for their products: GeoMedia, SpatialMedia, Map TV, or MapTube. Supported by a corps of volunteers (Cowen 2007), NAVTEQ's Map Reporter program offers further evidence that GIS have become media both metaphorically and literally.

The explosive growth of the GeoWeb and geographic information contributed by users through various application programming interfaces has made GIS powerful media for the general public to communicate, but perhaps more importantly, GIS have also become media for constructive dialogs and interactions about social issues. This is something we did not recognize 10 years ago, but it is obvious to us now.

This new role of GIS as social media can be understood from two perspectives. First, various users and contributors of online mapping sites have formed their own virtual community for exchanging information. Google Maps, Bing Maps, and Yahoo! Maps have attracted user communities in millions. Within 2 years of moving ArcGIS online, ESRI's ArcGIS.com website has attracted a community of over 300,000 world-wide (Dangermond 2011). Although most of the online postings and exchanges are of a technical nature (such as tips on mashup efforts, technical support on KML programming), recent postings by participants of the online mapping community have been covering topics of greater public interest, such as mapping of the location of bin Laden's death, Google Earth mashups of critical sites using data posted on WikiLeaks, tracking the diffusion of BP's oil spill in the Gulf of Mexico, and assisting in the relief efforts for earthquakes in Haiti and Japan. Undoubtedly, online mapping through the mechanism of VGI has become a language for citizens to voice their opinions on world events that are of interest to them. They are not only talking to themselves but also broadcasting about their findings to the world, or at least to those who have access to the Internet.

Second, interactions of online GIS users or neogeographers (Turner 2006) or neocartographers (Liu and Palen 2010) are not confined to cyberspace. A growing number of these actions have resulted in meetings in person and activities in real places. For example, participants of OpenStreetMap (OSM) in both North America and Europe have been organizing mapping parties over weekends to work together to map the road networks for their communities (Figure 1). OSM even gives specific instructions on how to organize these mapping parties (http://wiki.openstreetmap.org/wiki/Mapping_Weekend_Howto). URISA's GIS Corps program has been able to organize volunteers with GIS skills and send them all over the world to fulfill various mapping needs (http://giscorps.org). Many other websites developed in the tradition of citizen science have also attracted large numbers of volunteers, who then meet in person to collect data for various projects that benefit the community (e.g., MapAction, Walk Across Texas, Bike to Work Challenge, CitySourced). Just as social media can be defined as social interaction via the use of Web-based and mobile technologies, to turn scalable communication into interactive dialog, so too have these new trends discussed here shifted the role of GIS from being an arcane technology used by trained professionals, to a popular social medium for the general public to report problems and to build community.

In summary, GIS as media constitute a fundamental paradigm shift in GIS, from the old model of an intelligent assistant serving the needs of a single user seated at a desk, to a new mode in which GIS act as media for communicating and sharing knowledge about the planet's surface with and among the masses. During that process, GIS not only bring people together in cyberspace but also attract people to meet in person for the common good of their community. The paradigm change also implies a simultaneous shift of technical focus, from local performance to network bandwidth, and increases interest in issues of semantic

Figure 1. Mapping party by OSM contributors, Mountainview, CA, 11 February 2011 (http://community.cloudmade.com/blog/2009/02).

interoperability in place of earlier concerns with syntactic interoperability: in other words, sharing requires a common understanding of meaning, as well as a set of common standards of format.

2. (Social) Media as GIS: online social networking sites are increasingly location-based

In retrospect, the concept of GIS as media that we proposed 10 years ago only captures half of the story. During the past 5 years, media in general, and social media in particular, have become increasingly equipped with mapping and location-based features. In other words, media are increasingly becoming like GIS. Again, this new trend of media as GIS can be understood from two perspectives.

First, the mainstream media (TV, newspapers, etc.) are increasingly relying on GIS and geospatial technologies to report news and to tell their stories to the general public. Nowadays, Google Earth or Bing Maps are almost an integral part of the TV broadcasting of everything from weather and traffic conditions to major stories. In May 2004, the Association of American Geographers organized a national symposium on *Mapping the News* at the National Press Club: CBS News, US News and World Report, The New York Times, the Associated Press, The Chicago Tribune, Time Magazine, Reuters, the Los Angeles Times, USA Today, and the Washington Post, as well as numerous regional newspapers and Internet news outlets were represented (Richardson 2004). News organizations of every size use GIS (Herzog 2003), and a growing number of news media

have incorporated geospatial servers and mapping functionality as part of their websites: the Chicago Tribune and Time magazine use ESRI's MapStudio (recently renamed as MapShop), whereas the Seattle Times and Guardian use Google Maps. Using the geospatial mapping server hosted by the Guardian, for example, the public can create custom maps from data disclosed by WikiLeaks. Furthermore, news organizations have posted the original data online so that anybody can download them, conduct their own analysis, and draw their own conclusions (see, for example, mappingthefallen.org). Media organizations are not simply satisfied with using GIS as a mapping tool but are also increasingly interested in dealing with some of the fundamental issues of GIScience, such as georeferencing and interoperability (Carroll 2006), and working hand-in-hand with software developers to develop better mapping tools for journalism applications.

Media as GIS can also be understood from a second growing perspective that social media are increasingly location-based. Social media, led by MySpace, Facebook, Twitter, LinkedIn, and so on, have been described as one of the defining characteristics of Web 2.0 technologies. The phenomenon of social media is not only transforming the scene of computing but also stimulating social change of various kinds. The development of location-based social media during the past 2 years has moved social media from cyberspace to real place. Similar to the functions of Google Latitude (Figure 2), most location-based social media allow users to know and see on a map where their friends are physically located at a particular time. Facebook's announcement on 18 August 2010 to incorporate a new location-based service (primarily based upon Facebook users' GPS-enabled cell phones) represents the latest development of the so-called locative social media or location-based social networking (Thielmann 2010) for sharing personal location information, including such services as Gowalla, Foursquare, and Google Latitude. Location-based social media can be grouped into three major categories: (1) Social check-in sites (e.g., Foursquare, Gowalla, Blockchalk, BrightKite, Whrrl, and MyTown); (2) Social review sites (e.g., Yelp, Geodelic, Tellmewhere, Groupon, Blippy, and The HotList); (3) Social scheduling/events sites (e.g., Loopt, Plancast, Meetup, Eventful, Upcoming, Geoloqi).

In summary, the recent development of social media as GIS can be seen as an extension of the long history of journalism cartography (Monmonier 1999). Journalism is a professional activity that is inherently embedded in space and time, as what, where, when, and why are integral components of any news stories. *Where* has always been one of the fundamental questions guiding journalists, along with *who*, *what*, *when*, *why*, and *how*. So we are not surprised to see what may amount to a spatial turn in journalism and the traditional media. Indeed we fully concur with the renowned journalist Krissy Clark (2011) when she observed that 'The best journalism is like a map. It shows where you are in relation to others; it provides a sense of topography, a glimpse into a new world, or a better understanding of a familiar one. Ideally, journalism helps citizens and communities discover where they are, so they can better decide where they are going.' As demonstrated by the news organizations and location-based media so far, GIS and online mapping have come to play a very important role in location-based story telling, but conceiving of media as GIS also poses some interesting challenges for GIScience.

3. The convergence of GIS and media: key challenges for GIScience

Evidently, we have continued to witness the convergence of GIS and media during the past 10 years, and furthermore, GIS and social media have become more mutually constituted during the past 5 years, with online mapping sites becoming increasingly social and social

Figure 2. Location-based social networking: An example from Google Latitude.

networking sites more location-based. This dual trend poses some new challenges that deserve more attention from the GIScience community.

3.1. The data avalanche: Deep data for many?

The convergence of GIS with (social) media, coupled with advances in other location-aware technologies such as radio-frequency identification (RFID), quick response (QR) codes, WiFi, and smart phones, is moving us on a fast track to know where everybody and

everything are located on the surface of the Earth, at any time. We will continue to witness what Miller (2010) called the data avalanche, or computer scientists called big data (Caverlee 2010) or the exaflood. The new technological advances have made the first part of Tobler's first law of geography literally true – everything is connected to everything else. We now have technologies that can not only monitor individual movement in intimate spatial and temporal detail but also track a particular product for its entire life cycle from cradle to grave. In particular, GIS applications in the social and behavioral sciences have been confined in the past to what Manovich (2011) has called 'surface data' about the many (sociology, economics, political science, geography) and 'deep data' about the few (psychology, psychoanalysis, anthropology, ethnography, art history; methods such as 'thick description' and 'close reading'). With the growing popularity of social media, we no longer have to choose between data volume and data depth. We may now have deep data about many.

Although we have made important progress in recent years in harvesting spatial and temporal data from social media, the quality and credibility of those data for scientific research and decision-making still need further investigation. We need to explore new ways in which the fusion of GIS with social media can be deployed to promote the human-as-sensor paradigm (Goodchild 2007) in spatial-data generation. What would be the essential features of a global data service that harvested data from the Web and other sources, evaluated data quality, and advised users about fitness for specific applications? What protocols and procedures can be developed to link asserted, crowd-sourced social-media data with authoritative data to fill gaps in spatial data infrastructure?

This vision of synthesis is strongly associated with Digital Earth (Gore 1992), the creation of a single, unified perspective on distributed geographic information, together with the ability to visualize that information in a virtual reality. It raises substantial fundamental challenges for GIScience, in addressing uncertainty, matching data to application, tracking provenance, achieving semantic interoperability, and dealing with massive data volumes (Goodchild 2011a).

3.2. Spatial dynamics: Synthesis and visualization

The convergence of GIS and social media is also subtly shifting GIS from the relatively leisurely process of analyzing static data to a far more dynamic process of time-critical or real-time monitoring and decision-making. In the context of location-based social networking and media, GIS will involve much more real-time situation monitoring and assessment and will need new kinds of tools that treat information as continually changing (Goodchild 2010). The fusion of GIS with social media has also made it possible for the first time to operationalize what Miller (2003) envisioned as people-based GIS in real time.

Our growing capabilities of time-critical mapping and people-based GIS present us with an unprecedented opportunity to have a better understanding of the spatial dynamics of human behavior and societal transformation, but attaining this goal demands better tools to study spatial dynamics. We can concur with Yuan (2011) that the development of more robust data analysis and synthesis methods for studying spatial dynamics is a grand challenge for GIScience. This need is more urgent in the context of the convergence of GIS and social media. As of today, we still do not have the tools to automatically discover relevant information for a particular application over the Web, when a range of tools and websites are used by different groups of people.

To process the massive amount of social-media data from various sources with different levels of uncertainty, one crucial need is to synthesize information, ideally in real

time. Provenance and uncertainty of different sources should be maintained in synthesis, which is still a challenging issue in the network-science, database, and GIScience communities. How to conflate geospatial data with various accuracies, different levels of detail, and different generalizations is still an open question.

When an emergency happens, how can we find and access relevant information generated by different social groups? In addition, there is always a trust issue in accepting information generated by volunteers. An individual may be faced with a choice between available but potentially unreliable information synthesized by volunteers, and authoritative, yet possibly dated or temporarily unavailable, information from government agencies (Goodchild and Glennon 2010). Should he or she wait for the official information from government which may be slower, or should he or she trust VGI that is asserted without validation?

Should the next phase of GIScience follow Jim Gray's eScience – the Fourth Paradigm – and move toward a more data-intensive scientific discovery (Gray 2007, Hey *et al*. 2009)? Is it possible to synthesize geovisual analytics (which currently lack capabilities of handling voluminous social-media data) and social-media analytics and culturomics (currently lack spatial and mapping capabilities)?

3.3. New theories in GIScience: network, place, and multimedia narratives

We want to caution the GIScience community that the current enthusiasm toward data and infrastructure must be coupled with a keen quest for new theories and knowledge discovery. Our knowledge 'swims in the continuum of uncertainty and of indeterminacy' [Pierce cited by Couclelis (2003)]. The current tide toward a data-driven science should not blind us to a basic fact that our understanding of the world is not entirely determined by the quantity and quality of data alone. Certain aspects of the world are inherently unknown or unknowable due to the limitations of our logical apparatus and cognitive capabilities (Couclelis 2003). Even for data collection through the mechanism of crowd-sourcing, such as the OpenStreetMap effort, Haklay *et al.* (2010) have demonstrated that Linus' Law is applicable only to a certain thresold, beyond which adding more volunteers (the eyes of Linus' Law; Raymond 1999) seems to lead to little further improvement in data quality. Findings like these urge us to think more deeply and broadly about our theoretical endeavors. In light of the convergence of GIS and social media, we believe that our theoretical efforts should be intensified at least in the following three directions:

3.3.1. The development of new network-based ontologies

Until recently, our data models and representation frameworks have focused exclusively on unary spatial knowledge – knowledge about properties z present at locations $\mathbf{x}$ in space-time, often expressed as maps. The convergence of GIS and social media has resulted in more data about the properties z of pairs of places in space-time $\mathbf{x}_1,\mathbf{x}_2$ (binary spatial knowledge), such as who is following whom on Twitter, social affinity and interaction as demonstrated through Facebook links, or Internet information flows among major cities. These binary properties involving pairs of locations are not ideally suited to mapping using conventional mapping and cartographic techniques. Network-based representation models have been developed for environmental and disease modeling (Bian and Liebner 2007, Mao and Bian 2010), but representation of complex multilevel social networks remains a major challenge. Is there a way of using spatial information to generalize large complex social networks effectively, or to represent sparse and

inconsistent information in a way that makes the resulting analysis actionable? How can cartography and geovisual analytics contribute to representations of spatially embedded social networks? How can we use changes of edges in network graphs to represent changes of networks in physical space? What are other possible representations for network data: polygons, trajectory polylines, or other spatial forms? (see the final report of a 2010 specialist meeting on Spatio-Temporal Constraints on Social Networks at http://www.ncgia.ucsb.edu/projects/spatio-temporal/docs/workshop_report_final.pdf).

3.3.2. Formalizing place in GIS

Until recently, GIS has been dominated by perspectives from space using Cartesian coordinates according to Euclidean geometry. The massive amounts of VGI in general, and geotagged or location-based social-media data in particular, seem to revive our approach to the world from the perspective of place (Sui 2009), almost reaching the point of hyperlocalism dominated by 'the tyranny of place' (Haklay 2010). The convergence of GIS and social media prompts a new level of urgency for theoretical works to reconcile the world of space (traditional GIS) and the world of place (social media).

Agnew (2005, p. 84) observed that '. . . space can be considered as "top-down," defined by powerful actors imposing their control and stories on others. Place can be considered as "bottom-up," representing the outlooks and actions of more typical folks.' As Tuan (1977) and Casey (1997) have so aptly demonstrated, scholars in multiple fields throughout history have developed a vast repertoire of conceptualizations of place. Formalizing place in the GIS context will be both interesting and challenging; until recently, place has been off the intellectual radar screen of GIScientists, many of whom appear to use the two terms *place* and *space* somewhat interchangeably. Preliminary work has begun in the digital gazetteer literature (Goodchild 2011b). In a broader sense, the emerging critical GIS literature of the past 15 years has caused a subtle shift of focus from space to place, with its rich cultural dimensions; yet in GIScience, we still do not have an overarching theory of place or how to work with the concept.

3.3.3. Multimedia representation

This emerging world of place is increasingly represented by a combination of texts and blogs, photos, sounds, videos, and other means of human representation, real or imagined. Journalists have relied on this plethora of media representations to conduct location-based storytelling. Every place has a thousand stories, journalists tell them every day, and news organizations have archives full of them. With more and more location-aware technologies available, what methods and models can we follow to link GIS with this multimedia metaverse, to tell stories about the surface of the Earth better, and to develop a more coherent narrative for the future? The answers to all our questions may emanate from the landscape itself (http://murmurtoronto.ca). Are there more efficient, effective, and creative ways to link these stories to the places where they are rooted?

3.4. Social and political concerns: Equity, privacy, and sustainability

In big-data society, Manovich (2011) warned that people and organizations can be divided into three categories: those who create data (both consciously and by leaving digital footprints), those who have the means to collect (them), and those who have expertise to analyze (them). Today the first group includes almost everyone in the world who is using

the Web or mobile phones. The second group is smaller, but it is increasingly controlled by a few major corporations such as Google, Microsoft, Amazon, and Yahoo! that can afford the massive cloud computing infrastructure to host their various free services, through which they not only collect but also retain and process a massive amount of data. The third group is smaller still.

This trend raises some interesting social and political issues. Big corporations will increasingly have custody of big data, and their bottom line tends to be driven by profits rather the common public good. What are the implications? Will the growing popularity of social media, and social media integrated with GIS, enlarge or narrow the digital divide between the haves and have-nots (Sui 2011)? Currently, we do not have guidelines on when it is appropriate to collect information from people and to study people without their knowledge and consent. When is informed consent necessary for initiating research? Is there a way to preserve spatio-temporal patterns of social networks for research, but to protect privacy at the same time? Furthermore, what types of generalization and aggregation from statistics and cartography can be adapted to achieve these dual objectives and minimize the impacts of the stubborn modifiable areal unit problem (MAUP) in our analysis? How does the level of abstraction and aggregation limit the types of network questions that can be answered? In data-sharing projects, what practices and restrictions are necessary to prevent malicious uses of spatial data and spatially embedded network data? Another issue concerns the various degrees of information accessibility between different groups of people. How can we reach people without access to mobile phones, computers, and the Internet? Considering the fact that not all Internet users are necessarily social media users, how can we disseminate relevant information to people who have not adopted online social-networking services? In addition, online social networks are only a small fraction of the total set of real social networks; how can we collect data on social networks that are not represented in the digital world? What spatial sampling strategies will allow us to measure spatial, temporal, and social properties in hard-to-reach populations? Civil society has been integrated into the military infrastructure of digital media (Internet, GPS, etc.): will it subtly accelerate the process of militarization in society?

What are the environmental implications as a result of the convergence of GIS and social media? Will the trend stimulate more travel as a result of initial online contacts (thus potentially damaging the environment), or will it help the environmental cause by facilitating better planning and coordination of various human activities? Are the technologies of online social media and cloud computing ‘green’, in the sense that they create less environmental impact than the technologies they replaced? Or is it better to think of them as new technologies that add to humanity’s net environmental impact?

3.5. GIS education and public engagement

The fusion of GIS with social media will embed GIS and location-based services into people’s daily routines. This trend not only provides the GIScience community with an unprecedented historic opportunity for public engagement but also raises some fundamental questions about the meaning and role of GIS education.

For the long-term sustainable growth of GIScience, it is imperative that we start a serious dialog on what, why, and how we should educate and train our students (and the public) about GIS and related fields. Many have argued that the development of spatial intelligence must be given more prominence in education at all levels, if the next generation of users of geospatial technologies, including geospatially enabled social media, is to make effective and responsible use of them (National Research Council 2006). With GIS and

mapping technologies increasingly being used to illustrate issues ranging from earthquake relief and environmental disasters to human rights abuses and the on-going war on terrorism, what additional knowledge and skills are needed? Is GIS education ultimately about geographic education? If so, perhaps GIScientists can learn something useful from geographers' efforts to engage the public and even possibly to change the world in meaningful ways (Murphy 2006, Castree *et al*. 2010). The GIScience community has a proud record of engaging the public through research on public-participation GIS (we bring GIS to the public) and most recently through VGI and social media (the public and neogeographers bring their data to us). What new collective strategy should we develop in our outreach efforts and public engagement?

4. Summary and conclusions: plural views of the world and multiple futures of GIS

The convergence of GIS with media will continue to transform GIS in fundamental ways. In this editorial, we have identified a few topics that we believe are important, but we believe the future of GIS is inherently unpredictable. If there is one thing we are certain of, it will be that the future development of GIS will be on multiple tracks, as indicated by GIScientists' growing interest in such topics as the GeoWeb, Digital Earth, CyberGIS, virtual geographic environments, and cloud computing.

Perhaps one productive way for GIScience to proceed is to ride on the discipline of geography's communication turn and the spatial turn that is evident in media studies. Geography as an intellectual enterprise has undergone many fundamental changes during the first decade of the twenty-first century. Among these, a growing interest amidst geographers in media and communication studies – the communicational turn (Adams 2009) – is evidenced by the formation of the communication geography specialty group of the Association of American Geographers and the publication of new geography journals and textbooks devoted exclusively to media and communication geography. Although interest in media and communication has been identified as a relatively new phenomenon, geographers of various philosophical persuasions have long recognized the role of media and communication (and more broadly of language, maps, and GIS) in shaping space and place at various levels.

As social media become more locationally aware and people's experiences with their environment are more mediated, it is not surprising that media studies have witnessed a 'spatial turn' during the past 5 years (Morley 2007, Döring and Thielmann 2009), focusing on the complex interaction among people, space, and place as mediated by various media (Jansson 2007, 2009). Ground-breaking work has been reported by scholars in multiple disciplines under the general rubric of the spatial turn in media studies, ranging from the highly technical work of harvesting social-network data to the search for emerging geographical patterns of new social interactions enabled and revealed by social media (Backstrom *et al*. 2006, Lindamood *et al*. 2009, Intagorn *et al*. 2010). By linking GIScience research with these dual trends (geography's communication turn and media studies' spatial turn), we are confident that we can harvest fruitful research results that are intellectually exciting, technologically sophisticated, and socially relevant.

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