Advancing Geographic Information Science

The Past and Next Twenty Years

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Technological and Societal Influences on GIScience

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Abstract: This paper highlights and critically reflects on some of the most significant technological and societal influences on GIScience over the last 20 years, or since its inception. For the purpose of this book, which in the following chapters begins to sketch out likely paths for future directions of GIScience, one conclusion of this chapter can be taken for granted: In the next 20 years again significant external factors from technology and society will shape GIScience. This paper summarizes the discussions related a panel on the topic at the 2015 Vespucci Institute. The panel in Bar Harbor, moderated by Stephan Winter, included two invited presentations (by Xavier Lopez and Francis Harvey), and responses by two early career panelists (Benjamin D. Hennig and Myeong-Hun Jeong), and by two senior panelists (Tim Trainor and Sabine Timpf).

Keywords: Geographic information science, spatial information science, spatial information technology, GIS and society, neogeography.

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1 Introduction

This chapter highlights and critically reflects on some of the most significant technological and societal influences on GIScience over the last 20 years. The question whether, and if so, to what extent, technological and societal influences have impacted on GIScience, or helped shaping GIScience, is worth putting forward and thinking about in a volume that explores challenges for GIScience in the next 20 years.

The question is a fundamental one. When we consider the last 20 years, it offers us a better vantage of where we stand now and to think about the future. Also, it offers a vantage to reflect on the idea that any science is independent from technological changes or societal impact: Shouldn't science be the quest for underlying truths or laws that sustain any technological and societal influence? A romantic view, but a common view. We know that GIScience – as many other sciences, but in contrast to logic and mathematics – is an empirical science [19, 7, 8, 9], and empiricism is always driven by technological possibility as well as societal interest. This statement can be observed in physics as much as in geography, and thus holds for GIScience as well. Take privacy as an example. Privacy has come up as an issue on the research agenda only recently, and is a social issue: Technology exposes more and more of our movements, activities and thoughts such that a societal response for privacy protection is needed. As much as this response will apply regulations and legal enforcements, it will also rely on new knowledge and proof of techniques such as encryption and location obfuscation. Where we are will always influence what we know.

And yet, also empirical research should reveal over time a body of knowledge that holds over larger periods of time, i.e., is neither bound to particular technology (in times where technologies change so quickly, or innovation rates are exponential, as indicated by Moore's "Law" [14]), nor to a particular constitution of society. Its "laws" are statements which have been and can always be again confirmed by evidence. For example, research on people's ability to deal with vague spatial concepts, such as 'downtown' or 'Mt Everest', or on our ability to represent and reason with this vague knowledge in information systems, should have a considerably longer half-life than on people's views of where 'downtown London', 'the Alps' or 'Mt Everest' are.

Fortunately we know well from geography that different points of view help us gain a better scientific understanding. Critical thinking, instead of taking on one position, considers multiple positions, thus gaining deeper insights and developing more robust solutions. This chapter offers some of these thoughts. It is a result of a panel discussion on technological and societal influences on GIScience at the Vespucci's Summer Institute in GIScience 2015. The discussion was inspired by two presentations, which are summarized here. However, this chapter transforms this discussion by reflecting on the relationship between society, technology and GIScience as perceived today and felt to impact in the future. For the purpose of this book, one conclusion of this chapter can be taken for granted: In the next 20 years again significant technological and societal influences will shape GIScience.

2 The impact of technological change on GIScience

Over 500 years ago printing revolutionized the production (technological change) and accessibility (social change) of maps (Fig. 1). About 50 years ago computers became mature enough to allow people such as McHarg [13], Tomlinson [20], Fisher [6], Chrisman [2] and so many others to think about transforming maps for the information age.

Figure 1: The world first printed map, printed by Lucas Brandis in Lübeck [15].

And just above 20 years ago, with maturing database technology, artificial intelligence and understanding of spatial statistics, the term geographic information science was coined [8]. So while it is no surprise that technological change impacts on a field of knowledge it is still worth considering which technologies that came up over the past 20 years disrupted a linear development, or evolution, of the body of knowledge in GIScience. And while GIScientists have, and will continue to make significant, sometimes even disruptive contributions to society and knowledge, the following list concentrates on the external forces that have taken place in information technology and have influenced GIScience. This list has to stay selective, and thus, subjective.

- Evolving IT Platforms: Over the last 20 years, the underlying IT platforms used in GI Science have evolved profoundly from PCs to workstations, web services to mobile computing; and more recently, to Big Data (Hadoop) platforms hosted on the cloud. These IT platforms have transformed the underlying tools, data and techniques that GIScientists apply day to day.

- Databases: in the mid-1990s, commercial database vendors such as Ingres, Informix, IBM and Oracle introduced spatial databases. By incorporating spatial types, indexes and spatial query into a relational database, it was now possible to incorporate location analysis directly into mainstream IT operational and analytical applications. Over time, spatial databases supported richer spatial types including 2D vectors, to include raster data, planar topology, network topology, TINs, 3D vector models, and point clouds, thereby offering high-performance computing to applications using these spatial types.

- Free & Open Source Software: Young students and researchers of GI Science today are blessed with a rich assortment of mature open source and free GI technology. Products such as Linux, Java, Postgres, GeoTools, and MapServer are mainstream technologies for GI Scientists and professionals alike.

Researchers avail themselves to tools that are easy to acquire, adapt, and use. This was not necessarily the case in the era of commercial desktop GIS. Costs to academic departments have decreased while the range of tooling continues to grow.

• Spatial Data Infrastructures: In the 1990s and 2000s, the policy concept of National Spatial Data Infrastructures (NSDI) took hold throughout hundreds of developed and developing countries. National governments, in particular, began to recognize the importance of sharing public sector investments in spatial data broadly across the society and economy. While the promised infrastructures are late in coming – pieces exist but it is not yet a smooth experience –, key activities such as spatial data standards, public dissemination mandates, capacity building, relaxed intellectual property rights, and inter-organizational coordination have been closely studied and influenced by GI Scientists. Today's political emphasis on 'open data', 'open gov', and 'linked open data' have been enabled by these early efforts to make government spatial data more openly shareable.

• Global Positioning System: In May 2000, the U.S. Air Force eliminated 'selective availability', the intentional degradation of GPS signals for non-military purposes. This measure improved the precision of GPS signals to about 1 meter, making it feasible to develop broad range of precision surveying, navigation, and mobile location services. The adoption of GPS exploded across all sectors creating new research opportunities for understanding crowd-sourced movement of entities; management and analysis of massive streams of location data; and exploring predictive location behavior based on historical tracking patterns.

• Sensor Data Collection: the mainstream use of GPS signals for positioning, coupled with the miniaturization of low cost field sensors, ushered in the rapid use of sensor data collection at the turn of the century. Biologists tracked wildlife, trucking companies tracked and regulated the performance of their trucks, meteorologists used stationary sensors in the land, oceans, and atmosphere to monitor the environment. Sensors have crossed over into mainstream consumer use with the release of wearable devices. GI scientists continue to be advanced users of location-enabled sensors, and innovators in the use of Big Data sensor streams.

• World Wide Web: The most transformative technology innovation of this last period was the advent of the World Wide Web in 1993. While the Web transformed nearly all sectors of computing, it had a profound impact on the GI community. Before the Web, nearly all work done by GI Scientists was constrained to desk- top systems; after the Web most projects and research is oriented to or exploit the networked nature of the Web. The open standards, formats, and protocols introduced by the W3C, resulted in radical restructuring of how information was transported and published across the Internet. The Web enabled the rapid trans- formation from desktop and client/server platforms to Web Services, creating a foundation for a new class of Web mapping services.

• Web Mapping Services: In 1996, Barry Glick, a University of Buffalo Ph.D. graduate working at Donnelley, introduced MapQuest, a ground-breaking Web mapping service using government created data. MapQuest, and later services from AOL, Microsoft, ESRI, and Google provided mainstream Web users with the power to display maps, search features, geocode addresses, generate driving directions via Web browsers. Over time, these platforms enabled businesses, government agencies and citizens the ability to upload and display their own features on background map tiles. The underlying techniques pioneered by Glick and others – caching of map tiles, in-memory-based routing, crowd-sourced mapping – continue to make Web mapping services ubiquitous.

• Mobile Computing: Between 1999 and 2005, the promise of wireless location-based services (LBS) had been widely promoted. Japanese and European wireless providers brought early innovation in delivering powerful GPS enabled 3G phones. A constraint to these early mapping services were the proprietary nature of wireless carrier services that also blocked access to Web content. However, by 2006 US carriers had upgraded their 3G networks coinciding with Apple's release of the iPhone 3G smart phone. This device enabled app developers and users to directly access Web content creating a powerful smart phone platform that delivers GI services to nearly every mobile phone user globally. More recently, mobile application environments using HTML5 show promise in solving device-specific constraints within the World Wide Web.

• Social media & crowd-sourced data: By mid-2000, a new generation of open source Web and mobile computing services re-invented how mapping content was created. Citizen volunteers, field scientists, activists and amateur mappers began to generate and contribute spatial feature content to a new generation of Web mapping services, like Google Maps, OpenStreetMaps, and DBPedia. Michael Goodchild referred to this phenomena as volunteered geographic information [10]. Within a decade, the use of crowd sourced map data has challenged the role of government and commercial sector in the provisioning of vector mapping features.

• Linked Data: Linked Data is an evolution of by Tim Berners Lee's Semantic Web vision first introduced in 1999 [1]. Building on W3C standards and Web services, Linked Data focuses on the large scale integration and reasoning of data collections on the Web. Unfortunately, the dearth of formal ontologies, and immaturity of early RDF and SPARQL specifications slowed uptake of the Semantic Web. By 2011 these standards had matured and the availability of open source linking vocabularies, combined with a vast ecosystem of web mapping services, affords an opportunity to realize Tim Berners Lee's vision of a Web of geospatial features that introduces a potential area of research for GI Science.

• From data scarcity to data deluge: Over time – a process rather than a disruptive event – through spatial data infrastructures, open data initiatives and sensor data collection, GIScience is now confronted with unprecedented data volume, variety, and velocity. These advanced technologies not only bring forth computational innovation such as geospatial optimization and simulation, but also yield actionable insight from big data. GIScience therefore seeks today to resolve problems of dealing with and analyzing heterogeneous spatial data, integrating and synthesizing diverse data sources, and orchestrating collaboration, rather than data collection and pre-processing.

3 Societal influence on GIScience

With advancing geospatial technologies, and not least heavily supported by the increasing possibilities of the Internet, a revived interest in maps can be observed in recent years. Changing technologies and the revival of public interest in mapping led to the emergence of a large number of untrained cartographers producing maps and geographic data visualizations in the online world as well as contributing to the technological advances themselves. Corresponding to the list above, three underlying social outcomes can be identified immediately:

- Location data becomes mainstream: Map consumption and production moves from specialists to enthusiasts, and into everyday life.
- Democratization of tools and services: The combination of open source tools and Web services has broadened the developer base as much as the user base for simple and free mapping tools and apps that create, analyze and exploit spatial data.
- Open data initiatives: While free and public domain spatial data has been a feature of the US GI marketplace for a long time, other countries had different policies and values. But over the last two decades also European mapping and statistical agencies have reversed previous restrictive data dissemination policies and are now promoting open data initiatives for selected datasets. The growing availability of government-sourced open data is now driving a range open data services.

The growing availability of map data has made society aware of the limitations of navigation systems geared towards cars, and sparked a (still growing) interest in derivatives of navigation data for bicycles, pedestrians, public transport, wheelchairs or strollers. The drive towards individualized products not only had an impact on type or precision of geographic data but also engendered research on individual cognitive differences in, e.g., wayfinding or map perception. At the same time, prosumers are starting to contribute to datasets and products [10, 18]. However, as the revived interest in geodesign shows, prosumers have the right to expect more of GIScience, especially in terms of integrating the knowledge gained through analyzing and mapping geodata back into the original disciplines such as landscape design, forestry management or navigation.

In geography such trends have been identified by speaking of a methods-oriented 'neogeography' [21]. Neogeography is understood as combining cartographic techniques and GIS and bridging the gap between users and developers. The more recent field of neocartography[1] is seen even more broadly by looking beyond academia and science. It sees the described developments from the perspective of the cartographic community and does not exclude the untrained amateurs from changes in cartography and GIScience.

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[1] http://neocartography.icaci.org/

4 Perceived Constants

With the attempts to define GIScience in the literature (e.g., [8, 12, 11]) also attempts to define its research agenda came along. Thus, one approach to think about constants – challenges that have not gone away – is comparing these research agendas over time: an approach that is not new [12], and perhaps too obvious with a 20 year anniversary [11]. Similarly to research agendas also the evolution of a body of knowledge [4] reveals constants, or core elements. Some challenges that we perceive as significant staying with GIScience are listed in the following paragraphs.

Merging disparate data sets on its own is not too difficult. Making them work together seamlessly is more challenging. Tools are beginning to help with that challenge. Data integration means more than joining two or more data sets. Data integration can create new data with new meaning, even if it is not yet clear how this can happen and what are its effects.

Over time, spatial data have been made increasingly useful through organized and disciplined standards (metadata), through helpful tools (vendors and open source software), and through increasing amounts of needed, and in some cases, unintended geospatial data (SDIs, VGI). Also over time, the precision and accuracy of geospatial data has increased. Finer and finer resolutions have provided information that allows data exploration at levels significantly greater than 20 years ago, but this trend has not stopped yet. It begs also the question of data quality, a topic that has been well researched and published, but which has not been applied to most of the data that is used. Simple (and sometimes untrue) statements appear in metadata catalogs, but in the end feature-level data quality is needed to be able to answer that question accurately. Once the "goodness" or fitness for use of the pieces can be determined, then more general statements about the quality of data sets can be determined.

Many phenomena GIScientists study range over several spatial scales. Within geography the range might be smaller than in physics, but it still goes from smaller than a person to the whole world. Although the field is aware of this fact and numerous papers have been written on this topic, there is as yet no definite body of wisdom how to deal with multi-scaled systems or phenomena or how to deal with coupled systems spanning over different levels of scale.

Maps and existing approaches to mapping emphasize static properties or geographic forms, whereas geographers and ecologists are often more interested in mapping the process(es) that produced these forms. While maps (*plural*) help with this endeavor, the field needs to agree upon a handling of (geo-)process in order to get at the original research questions behind the representation. Mathematical and more recently agent-based simulations have brought a notion of process into the field that differs radically from the notion of a geoprocess – however an integration of these two approaches would ultimately benefit GIScience.

Another constant, although an underrated, is ethics. Ethics accounts for the values of our engagements in science and helps formulate our choices, values and responsibilities. In Geographic Information it covers all aspects from what is observed (or not), who has access, for which purposes is it used, and how is it communicated, and concerns system design [16, 17, 3] as much as people building or using these systems [5]. As a constant charge for reflection and responsibility, ethical questions do also change with societal values over time (as they are different between societies).

5 Relationship between technology, society and GIScience

After reflecting on the opening question – the question whether, and if so, to what extent, technological and societal influence have impacted GIScience, or helped shape GIScience, is worth putting forward and thinking about in a volume that explores challenges for GIScience in the next 20 years – it is quite clear that this chapter scratches the surface of many influences, both of technology and society. It answers the opening question positively: the field has been heavily influenced by these external factors. Perhaps what is always going to be most important is not the degree of completeness in the reflections, but the degree they enable GIScience to develop and progress through critical thinking.

Fast technological progress meant that the field had to adapt the handling of geodata/geoinformation to this progress, from static to streams, from scarce to big, from unstructured to structured and semantically rich data, from vector to raster to linked data. Over this progress it seems that the same questions have been asked repeatedly, always within a different data paradigm, and that we were ever adapting algorithms to these new paradigms. The field thus seldom got to the point to ask what the data was being used for and how to support the 'handling' of data in prosumer contexts, illustrating that with technological and societal influences (changes) some questions remain constant.

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