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Geographic Information Science I: Why does a smart city need to be spatially enabled?

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Abstract
In this report I propose to examine the concept of the 'smart city' from the standpoint of spatial enablement. I analyse emerging research on smart cities, particularly those addressing the potential role of GISciences in the development and implementation of the concept of smart cities. I develop the idea that the intelligence of a city should be measured by its ability to produce favourable conditions to get urban operators (citizens, organizations, private companies, etc.) actively involved into sociospatial innovation dynamics. To obtain such a commitment, I believe that operators should be able to develop and mobilize (digital) spatial skills so that they could efficiently manage their spatiality. In other words, I argue that a smart city is first of all a spatially enabled city.

Keywords
citizen sensor, digital city, GIScience, intelligent city, live city, open city, smart city, spatial enablement, spatial skills

I Introduction

Four numbers alone are enough to capture the importance of cities in our modern societies, and the amount of pressure they have to deal with: cities cover only 2% of the Earth's inhabited land area; 50% of the population on the globe live in cities (80% by 2050 according to the United Nations); cities account for 75% of total energy consumed and 80% of CO_2 emissions. Today, the concept of smart cities is a solution proposed to cities to meet these challenges, and is the one receiving the most media attention. Although the idea of the smart city resulted from a very aggressive strategy developed by information technologies giants such as IBM or CISCO, it was quickly taken up by researchers from various disciplines including GISciences and their related areas.

To date, no consensus has been reached from this proliferation of interests. Some authors would rather use the terms 'urban intelligence' (Komninos, 2006; Simone and Ratti, 2011), 'WikiCity' (Ratti et al., 2007), 'City 2.0' (Eychenne, 2008; TEDxCity2.0, www.ted.com/pages/tedx_tedxcity), 'ambient city' (Streitz, 2011), 'real-time city' (Kloeckl et al., 2012) or even 'ubiquitous city' (Jackson et al., 2011; Shin, 2009). For the first time in its history, the TED Prize 2012 was awarded not to a person, but to a concept: City 2.0. All of these terms refer to the idea of improving urban functions

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and services provided to the population not only through innovation (Florida, 2008; Winters, 2011), but also through the combination of networks (especially wireless), sensors/actuators and the active commitment of citizens (Batty et al., 2012; Roche et al., 2012).

Basically, the idea of the smart city is grounded in the current transformations of our urban societies. Today's society, especially urban society, favours the notion of hyper hypermodern, hyperconnected, hyperlocalized. Actually, hypermodern society is characterized by at least three major transformations that all have more or less to do with geolocation. First, there is the dematerialization of a growing segment of society. In the 1950s Claude Lévi-Strauss described 'three humanisms' characteristic of occidental history. Following his footsteps, Doueihi (2011) identified a fourth humanism, digital humanism, to refer to the type of society in which new mediums (books, maps, multimedia, augmented reality) cannot be fixed in space or stabilized over time. As a matter of fact, the digital world has become a 'civilization' in which how we look at objects, relationships, values and space has drastically changed. Second, there is what we call the 'global location age' in which personal space has turned into a potential place for instant capture and sharing of events (Lussault, 2007, 2009, 2013). Personal spaces are being staged and, like the Leibnizian monads remobilized by Latour (2009), they carry a locally rooted version of the global whole they form. Last but not least, there is the growing importance of digital socialization (Doueihi, 2011). The popularity, along with the major role played by social media and networks in both information and the mediation of social relations, is yet another characteristic of the hypermodern society. Geolocation, and indirectly GIScience, is a key component of these social media and networking sites (LBSN as defined by Zheng, 2011). Within this geocommunication context, that is to say a location-based communication, urban citizens are called upon to act as active sensors, to stage their personal spaces and to share their spatiality. Therefore, citizens become sensors (Goodchild, 2007), with a varying degree of awareness and involvement, but always tracked, always traceable.

I would like to take the opportunity of this annual review series to focus on the role of Geographic Information Sciences in the development and implementation of the idea of smart cities. I aim to show the extent to which research on smart cities can be used to illustrate interesting and important new developments in GIScience research and practice. This first report offers a discussion of the concept of smart cities from the standpoint of 'spatial enablement'. Isn't a smart city, first and foremost, a spatially enabled city? The first section of this first report focuses on a classical literature review. The second section proposes to explore more precisely how GISciences could contribute to making cities smarter based on a complementary meta-analysis that addresses the key concepts of smart cities, with a particular attention to those shared with GISciences.

II The rise of the smart city

Based on an extensive and pluridisciplinary literature review about smart cities, I highlight three main trends.

First, some mainly from the IT and (geomatics) engineering domains (Hernández-Muñoz et al., 2011; Mitton et al., 2012), use the idea of smart cities to advocate the fact that urban infrastructures based on the systematic use of information and communication technologies show greater efficiency. Wireless networks, and particularly sensors, have become the backbone of urban functions. They provide efficient solutions to integrate infrastructures (transport, energy, water, communication, etc.) within the same architecture and manage related services from one single control centre. The Operations Center of the City of Rio, and its integrated system designed by IBM,

is the perfect example of this approach. Komninos (2002) considers four possible meanings for the term 'smart city'. Two are at the origin of this 'techno-centred' vision. The first one refers to the use of digital applications to develop cities via the dematerialization of information and knowledge (cyber- or e- government). The second meaning refers to the communities and territories that have undergone a digital transformation, making them intelligent because they are connected. Gil-Castineira et al. (2011) show, in the project Ubiquitous Oulu Smart City, improved communication between citizens and services thanks to an informational structure named RunWithUs, based on easy-to-use interfaces and web services, including intelligent street furniture (Internet of Things), and on the widespread availability of the wireless network. Based on this hypothesis, several projects are being developed in Asia, with a focus on active sensor networks and ambient computing. South Korea is a typical example, especially with the Songdo International Business District (SIBD) project built from scratch on 1500 acres (610 ha) (Hancke, 2013; Jackson et al., 2011; Jang and Suh, 2010). Other research also brings to the fore the key role of location-based engineering (Tao, 2012). Roche and Rajabifard (2012) use the transversal and inclusive dimension of spatial referencing in order to make spatial data infrastructures (SDI) the heart of the technology platforms of smart cities. Location-based services, 3D models, imaging or augmented reality are also considered as urban mediation supports (Daniel and Doran, 2013).

Second, some others see smart cities as an opportunity to rethink the notion of urbanization with a more systemic approach, reintegrating the concept of sustainable development into the urban context (Chourabi and Nam, 2012). Doran (2012) provides a city model based on sustainable development principles, and built around three components: economic (governance, innovation), environmental (smart grid, climate change) and social (urban mediation, participation). More specifically, Anthopoulos and Vakali (2012) linked together four dimensions related to urban planning (environmental protection, sustainable residential development, best use of resources and consistent growth support) through their own analysis of the components of smart cities (administration, infrastructures, information, service, citizens). They revealed that these components are directly aligned with the dimensions of urban planning, and that, in turn, urban planning benefits from smart cities. Yet, based on a more constructivist vision, Hollands (2008) highlighted the various myths surrounding the idea of the smart city. He challenges the optimistic vision (positivism) that considers the use of technological infrastructures as a means to ensure optimum efficiency with regards to urban planning and sustainable development. He offers a more progressive vision focused on individuals and social capital.

Based on this last vision, a third trend emerges. Others authors (Gil-Garcia et al., 2013; O'Grady and O'Hare, 2012; Schaffers et al., 2011; Zygiaris, 2013) associate the idea of smart cities with an active commitment of citizens to urban innovation processes, thus overhauling city governance through open and bottom-up procedures (government, data). Komninos' (2002) third meaning of the smart city is based on the primacy of citizens in communication and information systems supported by technology. The fourth and last one refers to urban areas integrating the digital (technology) and citizenship (individuals) dimensions in order to improve innovation and learning, as well as knowledge mobilization (Kourtit and Nijkamp, 2012; Nam and Pardo, 2011; Naphade et al., 2011). Smart cities develop on territories characterized by their strong ability to innovate and learn, and shaped by the creativity of urban actors (population, institutions) who use digital infrastructures as a privileged means of knowledge management and communication (Komninos, 2009; Komninos et al., 2013; Schaffers et al., 2011). This trend often draws fierce criticism. In her LIFT11 conference keynote in

Marseille, France, Saskia Sassen[1] specified that the main challenge is to urbanize technologies rather than to use technologies that de-urbanize cities. In a provocative talk, Greenfield (2013), author of Everyware, supported the idea that the smart city, as promoted by IT giants, is incompatible with making sense and addressing the sensitive and informal dimensions of a city, which are core to the development of a true citizen urbanity. Haque (2012) also emphasized the weaknesses in the approaches adopted to support the implementation of smart cities. Based upon an analysis of the main projects developed by IBM and CISCO, he came to the conclusion that most initiatives today are being driven by technology and mainly reflect the basic functionalities of the Internet of Things (IoT); that they are essentially 'one size fits all' in nature and follow a top-down strategy; that they reduce the idea of smartness to the notion of efficiency (without giving consideration to improving the flexibility and adaptability of both operations and services provided by cities); that they reduce the urban model to a coherent and indivisible whole, with little prospect to facilitate multi-scalar projects; and, finally, that they consider citizens only as passive sensors (for instance, through tracking their movements).

III What can GISciences do for making cities smarter?

In order to understand the concepts underlying the smart city, and to complement the classical literature review offered above, I focus here on what specialists say about it, and what kind of words and concepts they use. I carried out a meta-analysis of 67 recent publications (24 peer-reviewed scientific papers, 23 studies by private companies and 20 reports by local governments (essentially cities). This analysis highlights the fact that the smart city is still and foremost a project in development, aiming at: (1) efficient operation of an infrastructure based on communication and information technologies, networks and sensors so as to optimize its 'routine' operations (Hernández-Muñoz et al., 2011; Mitton et al., 2012);[2] (2) creating methods of governance restructured around informational infrastructures and open services/data, based on collaboration and partnership, to improve the efficiency of the services provided to the population, especially in terms of energy, water and transport (Alawadhi et al., 2012; Caragliu et al., 2011); and (3) renewing the forms of active urban citizenships built on the participatory involvement of all actors, with a concern for urban innovation (Kourtit and Nijkamp, 2012; Nam and Pardo, 2011; Naphade et al., 2011; Roche et al., 2012).

A more refined analysis of geospatial subjects points out that geospatial references focus mainly on three different areas. One relates to geographical and administrative scales (local, municipal, regional, national, international). Considerations about smart cities are not confined to the municipal level; they rather reposition smart cities in their networks. It is no coincidence that the reports produced by municipal organizations include numerous references to scalar issues. The second area covers the key concepts of spatial analysis and research (areas, local, where, space, place, location, scale, spatial), which is undoubtedly the most interesting theme for this report. A consensus on the concepts seems to emerge across the three different publication types. The last area deals with explicit GISciences methods and tools (maps, geographic information, GPS, geospatial, GIS). Researchers seem to be almost the only ones to correlate this dimension to smart cities. Moreover, it is surprising to find so little or no explicit reference to GIS or SDI in the literature, especially in professional reports.

In a recent article, Batty et al. (2012) support the need to formalize a science for smart cities. This is even more explicit in Batty's latest book (2013). While recognizing the importance of the role played by information and communication technologies (ICT), they also make clear that human capital is fundamental to city intelligence. This human capital corresponds to and

is associated with those who use physical and informational infrastructures (especially the digital city) efficiently. In this context, Batty et al. (2012) identify a wide range of key concepts that comprise urban intelligence: representation, connection, coordination, measure, networks, movements, participation or even sensors, to list only the most important ones. Geospatial intelligence is clearly referred to as a primary resource to support this intelligence, and the set of 10 core concepts of geospatial information proposed by Kuhn (2012) – location, neighbourhood, field, object, network, event, granularity, accuracy, meaning and value – fully illustrate the above statement.

If there is a consensus today about the crucial role of information and geospatial technologies in implementing the concept of smart city, what can GISciences do specifically to make cities smarter? In order to provide some possible answers, I consider the use of GISciences in four of the fundamental dimensions of smart cities below.

GISciences can support the development of the *intelligent city*, that is to say of the social infrastructure and civic spatial engagement practices. Crowdsourcing and VGI, including location-based social networks, stand out today as key geospatial data sources indicative of the pulse of a city (Ratti and Haw, 2012; Vaccari et al., 2010). Connected urban citizens, acting as active sensors, have the capacity to contribute even more efficiently to the spatial intelligence of cities; they have the potential to make a meaningful contribution to the citizen science of cities. Indeed, GISciences offer at least three different types of potential support. Mobile positioning technologies can be designed to centre on the individual, and provide more user-friendly interfaces (Batty et al., 2012). Methods for the validation and qualification of VGI can ensure their coherence and smooth integration within municipal SDI, for instance (Goodchild and Li, 2012). Teaching approaches can improve citizens' spatial skills and provide them with spatial thinking advanced abilities (Li et al., 2012) so that they can not only collect and diffuse geospatial data, but also participate in their analysis (Haklay, 2012).

GISciences can also support smart cities by dramatically enhancing the *digital city* dimension, and in particular the urban informational infrastructure. When the concept of digital Earth, a digital model of the Earth (Goodchild et al., 2012), is applied to urban contexts, it closely reflects this digital city dimension. Indeed, ongoing work in the fields of SDI (Roche and Rajabifard, 2012; Roche et al., 2012; Tao, 2012) and big data (Janowicz et al., 2012; Kitchin, 2013) offer possible methodological and technological solutions to support cities in the implementation of a digital urban model. More particularly, and to use the words of Craglia et al. (2012), the next generation of digital cities will not be single systems. Rather, they will be multiple connected infrastructures related to various components of the city (transportation, land tenure, BIM, etc.), and based on open access and participation across multiple technological platforms to address the needs of different audiences (citizens, private companies, public organizations, etc.).

The governance dimension of smart cities is based on a form of open democracy; this *open city* can benefit from the recent advances in GISciences. The concept of open democracy is threefold: cooperation (transversality and partnership), participation (co-construction of public policy, consultation, debates) and transparency (open data and dataviz: to explain use of images). GISciences are particularly relevant in terms of participation and transparency. For instance, they provide technological mechanisms and infrastructures to develop access and delivery platforms (even from mobile devices) for open data, not just explicitly geospatial data, ensuring their qualification, their analysis, adding metadata and standards adapted to a variety of audiences, and enhancing readability through multimedia and (carto)graphic representations (Batty et al., 2012; Tao, 2012). The specific fields

of geocollaboration, public participation GIS and participatory geoweb fields diverse resources to consolidate the participative dimension of the *open city* (Johnson and Sieber, 2012).

A smart city is also a living urban fabric that is continuously being reshaped and is adaptive to change. This *live city* dimension of the smart city, which the Oxford Programme for the Future of Cities (2013) has even termed 'flexible city', also greatly benefits from GISciences, and especially from geodesign. Carl Steinitz (Harvard Graduate School of Design) considers that 'geodesign is geography by design' (Steinitz, 2012). As a matter of fact, geodesign does not really refer to a new concept (Roche and Goodchild, 2012). Nevertheless a new dynamic aiming at providing significant updates started in December 2008 at the NCGIA special meeting on 'Spatial Concepts in GIS and Design' (NCGIA, 2008). Following this meeting, the first Geodesign Summit took place in Redlands (CA) in January 2010, followed by a second, third and fourth in 2011, 2012 and 2013. Geodesign was defined by Mike Flaxman[3] at the first Geodesign Summit as:

> a set of techniques and enabling technologies for planning built and natural environments in an integrated process, including project conceptualization, analysis, design specification, stakeholder participation and collaboration, design creation, simulation, and evaluation (among other stages). Geodesign is a design and planning method which tightly couples the creation of design proposals with impact simulations informed by geographic contexts. (Flaxman, 2010a)

GeoDesign, with a big D (Goodchild, 2010), as part of GISciences, provides innovative, creative, deliberative, uncertain, multi-actor, multi-scale and multi-thematic methods and tools to design smart cities and their physical and 'senseable' structure.

IV Conclusion

A smart city is a city that is able, in a multi-faceted territory, to efficiently mobilize technological innovations so as to anticipate, understand, openly discuss, act and serve many actors with a wide range of profiles. To do so, a smart city operates in four main dimensions: the intelligent city (its social infrastructure), the digital city (informational infrastructure), the open city (open governance) and the live city (a continuously adaptive urban living fabric). Today's urban actors are connected and mobile actors. They are no longer mere consumers of urbanity, but true producers of these intelligent cities. To do so, citizens mobilize a range of skills among which spatial skills are pivotal. These actors' commitment, and especially their spatial commitment, is essential to the effective functioning of the smart city's four dimensions.

A smart city needs to be spatially enabled. Indeed, a 'spatially enabled society is an evolving concept where location, place and any other spatial information are available to governments, citizens and businesses as a means of organizing their activities and information' (Williamson et al., 2010). Basically, according to this definition, spatial enablement refers to the concept of location as a way to organize and manage spatial processes. As mentioned by Roche et al. (2012), more recent definitions state that in order to be considered spatially enabled, an organization (city, local government, society), must first consider location and spatial information as common goods, and then make them available in order to stimulate innovation. Therefore, in order to become spatially enabled, three conditions are required. First, citizens have to be 'spatially literate'. Second, spatial enablement requires a conducive environment to open and share spatial data. Last but not least, there is no possible spatial enablement without globally unified geospatial standards (Africa, 2011). GISciences directly contribute to increasing the intelligence of cities. Research on VGI and crowdsourcing, on SDI, big data or digital urban models, and on open data, participatory GIS, and geodesign offers a wide range of concepts, methods and

technologies providing effective support for the development and implementation of smart cities.

I have reviewed some of the areas of GIScience research addressing these issues, in order to highlight the extent to which the geospatial dimension is crucial for 'smartening up' cities. Of course, the role played by GISciences in the various dimensions of smart cities deserves further analysis, with respect to their particularities and relations. The recently initiated GeoThink.ca (http://geothink.ca) project provides a relevant framework for such an analysis. Indeed, GeoThink will especially explore how location-based technologies and social media may transform the way Canadian cities and citizens communicate with each other. In future reports I will give further consideration to how researchers in GISciences and geography theorize the concept of 'places' in the context of smart cities and related to the interfaces acting as key operators for digital spatiality.

Notes

1. Sassen's keynote is available at: http://videos.liftconference.com/video/2895375/saskia-sassen-the-future-of.
2. Batty et al. (2012) refer to this as the city 'operation system' or 'OS'.
3. The material presented by Mike Flaxman at the Geodesign Summit in Redlands is also available in Flaxman (2010b).

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