
senseable city lab:.::

Are 'Smart Cities' Smart Enough?

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We live in the Global Location Age. "Where am I?"
is being replaced by, "Where am I in relation to everything else?"
Introduction of PennState Geospatial Revolution Project
(http://geospatialrevolution.psu.edu/)

Abstract

In our contemporary societal context, reconfigured by wide spread impact of Geo-localization and wikification on urban population's everyday work and life, two related concepts, "spatially enabled society" and "smart city", have emerged from two different but related fields: the Global Spatial Data Infrastructure community drives the former while practitioners and researchers in urban planning, urban studies and urban design are more concerned with the latter. We believe that technology enhanced, ICT-driven solutions that spatially enable the members of urban populations, contribute to smart operation of cities, and we suggest that a dialogue between the communities that foster these two notions needs to be established. We seek to provide an ontology of categorically different, but still related, spatial enablement scenarios along with speculations on how each category can enhance the Smart City agenda by empowering the urban population, using recent projects by the MIT SENSEable City Lab to illustrate our points.

KEYWORDS: Spatially Enable Society, Smart City, Spatial Skills, SDI, Real-time Information, Geo-localization, Wikification

1. Introduction: Can We Have a Smart City without a Spatially Enabled Urban Population?

Geo-localization and Wikification have spread throughout society, including citizens' everyday work and life. Now is the age of Googlemap-mania where everything is about geo-location and geographical information, and the era of Wikinomics manifested in the current trend in day-to-day social organization towards democratization of access to information, peer-to-peer information sharing, and crowdsourcing the mass production of collaboration-based Information. Under such circumstances, sensor networks, real-time information flow and location (of everybody and everything) become important parts of today's life, especially urban life.

In this reconfigured societal context, two concepts have recently emerged: "spatially enabled society" and "smart city". These two concepts come from two different disciplinary fields, two different communities. The Global Spatial Data Infrastructure - GSDI- community mainly drives the discourse on spatial enablement; while smart city, as a concept and a mode of operation, emerges from practitioners and researchers involved in urban studies, architecture, urban infrastructure, and engineering. In this article we maintain that a city cannot fulfill the requirement of being smart in its most comprehensive sense unless the technologically enhanced, ICT-driven urban solutions that are considered in smartening up the city, are also contributing to the empowerment of the urban population by spatially enabling them. Yet, in its present form, we lack a cross-disciplinary dialogue about these concepts: the "smart city" and the "spatially enabled society". Only very few formal references are made by both of their reference communities regarding each other's work. In this paper, we try to address this disconnection and explore possible contributions of the notion of 'spatial enablement' to the 'smart city' debate in the age of Geo-location and Wikification.

2. Smart City and its Relation to Technology

2.1 Providing a Comprehensive Definition of "Smart City"

As for smart cities, the urgency for improving the cities' capacity for competitiveness and sustainable growth has focused the attention of city officials, place makers and policy makers on securing a desired level of quality in areas such as housing, economy, culture, and social and environmental conditions. This challenge fuels the worldwide obsession with making cities smart, and to this effect, the Smart City as a label, concept, and agenda has been quite fashionable in place-making discourse and practice in recent years.

Based on our literature review of the field, we believe that in providing the most comprehensive definition of smart cities, urban performance should be gauged against a city's hard infrastructure and its attention to the environment;[1] the accessibility to and use of information and communication technologies (ICTs), for both urban population and public administration (Graham and Marvin, 1996; Roller and Waverman, 2001); as well as its human and social capital, manifested in decisive factors such as the presence of a creative class (Florida, 2002), the education level of urban population (Berry and Glaeser, 2005; Glaeser and Berry, 2006), and the generation of Localized Knowledge Spillovers (LKS), originated from face-to-face contact between peers in an urban environment (Breschi and Lissoni, 2001; Fu, 2007; Capello, 2009). Furthermore, the smartness of a city should be measured by its participatory governance, its smart economy, its smart urban mobility, its smart environmental strategy and management of natural resources, and the presence of its self-decisive, independent, and aware citizens leading a high-quality urban life. In collaboration with the Centre of Regional Science at the Vienna University of Technology (lead partner), as well as with the OTB Research Institute for Housing, Urban, and Mobility Studies at the Delft University of Technology and the Department of Geography at University of Ljubljana, a European Smart City research project was carried out from April 2007 to October 2007, aiming at ranking 70 mid-sized European cities in terms of smartness, based on an evaluation model developed by the research group.[2]

In its current state, the vision of a smart city is one-sidedly fostered by a technologically enhanced worldview of the urban condition. This idea is in line with the European Union's focus on achieving urban growth in a “smart” way for its metropolitan areas, manifested in the OECD and EUROSTAT Oslo Manual of 2005, featuring a wired, ICT-driven form of development.[3] Furthermore, Caragliu, Del Bo and Nijkamp (2011) wrote an article providing an interesting set of decisive factors in identifying smart cities. In visions that companies such as CISCO and IBM offer through their initiatives for smart cities, the latter are envisioned as wired cities with connectivity as the main source of their growth and the driver of their effective performance, which are saturated with ICT-driven solutions to urban problems that

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[1] Many recent books are revisiting the importance of urban form in shaping the experience of urbanites. A well-known aphorism by Winston Churchill goes: *"We shape our buildings, and afterwards our buildings shape us."* The same belief lies behind Jan Gehl’s latest book (2011). In the first chapter, he states: *“First we shape the cities – then they shape us.*”

[2] For more information on the project and results, please see the website at http://smart-cities.eu, as well as their final report titled "Smart cities Ranking of European medium-sized cities," available at
http://smart-cities.eu/download/smart_cities_final_report.pdf http://www.smart-cities.eu/model.html

[3] http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/OSLO/EN/OSLO-EN.PDF

are deployed top-down by city officials and governmental agencies. For example, the Cisco's Smart+Connected Communities initiative is geared towards the use of intelligent networking capabilities to connect people, services, community assets, and information into a single pervasive solution by leveraging real-time information and applications, with the network as the underlying service delivery platform. Following the same route, in December 2010, the Brazilian city of Rio de Janeiro and IBM signed an agreement to build a public information-management center for Rio de Janeiro. The plan is for the Center to integrate and interconnect information from multiple government departments and public agencies to improve the city's responsiveness to various types of incidents, functioning as a modern, urban-scale control room. The operators of this control mechanism will be provided "with a single, unified view of all the information that they require for situational awareness." Since the Center will be equipped with a platform for consolidating data from urban systems for visualization, monitoring, and analysis, it will enable city leaders to make decisions in emergency situations based on real-time information. Pedro Almeida, Smarter Cities Director for IBM Brazil, predicts that this IT platform will soon be able to gather data on all incidents and events occurring in the city. This means that the operators of Rio's Center will soon be given access to an unblinking eye monitoring the city, so that governmental and public employees can anticipate events in time to provide efficient response.[1] Most of the time this technological view does not take into account the role an empowered human and social capital could play in transforming our cities into intelligent operating mechanisms.

2.2 "Smart City" and Conception of Technology as In-use

The deployment of connected sensors and immersive information technologies that suffice for a city to become 'smart' has its tradition in a positivist perspective that sees technology as salvation to both perceived and unperceived problems, examples of which date back to Friedrich von Knauss' "Wundermaschine" (miracle machine) from the mid-eighteenth century (Argyris and Schön, 1995). In this vision, the deployment of technology itself, and its magical, awe-inspiring effect on the observer, cannot solve problems while disregarding the way by which technology is used and embraced by a user community. Contrary to the view of technology as detached from the specificity of its context of use, is the so-called "technology-in-use" perspective, common to the Science and Technology Studies domain. Whereas the espoused technology is what we buy and install as predefined integrated modules in hardware and its accompanied software, how we use it is not predefined by any means and depends on the context within which we use technology according to our needs, skills and interests. Inquiring into these two different aspects of technology, Argyris and Schôn (1995) demonstrate that there is often a contradiction and a certain level of conceptual separation between the two. Moreover, both in theory and practice, what matters in evaluating the global efficiency of a technology is not the predefined commitments of a certain technology, but its regular use in the real world.

[1] http://www-03.ibm.com/press/us/en/pressrelease/33303.wss

Beside the specific performance measures of a technology, this approach focuses on the broader dynamics of technology as a part of organizational structures, use modalities, workflows and socio-cultural meaning systems tied to it. Troubles arising from smartening up our cities using ICT-driven solutions to meet urban challenges, do not relate to technological inefficiency. Indeed, when a smart card public transport ticketing system introduced in Jakarta breaks due to a limited consideration of the operational environment, or, the one in Venice does not deliver origin-destination data due to the specific implementation, it is not the *raison d'être* of technology that should be reconsidered, but the implementation that lacks integration and coordination into existing contexts and their dynamics. The results of such oversights are not neutral. They are considerable due to costly investments made without the rightfully expected direct and indirect value return for citizens, and they might also compromise previously successful solutions that may not be reversible after a systematic change in technology.

To this effect, envisioning smart city related technologies as technologies-in-use (such as sensing, actuating and information technologies in cities) means to begin with the study and consideration of existing dynamics of specific urban contexts, and its spatial and socio-economical organizational structures, in order to empower urban communities to successfully tackle the challenges they face. The technologies deployed in the process of smartening up our cities will succeed if they are embraced and integrated into the modalities people chose to live their cities and they will fail if their deployment is seen as the end of a process instead of a beginning.

As a matter of fact, the proliferation of digital technologies has greatly enhanced opportunities of leap-frogging. Once in place, disruptive technology systems can change the underpinnings of how things are done, and enable solutions to be developed, though previously unthinkable, as for the cellphone adaption in African countries without landlines and the diffusion of the Internet. Yet, neither of these systems offers solutions. Instead, the more they are accessible to people in their daily routines, the more they are powerful. When planned and implemented carefully, technology connections allow citizens themselves to become actuators in their city, enabled to interact meaningfully with and through space. This coincides with the core idea of spatial-enablement.

3. Smart City and its Relation to Spatially Enabled Society

3.1 Technological Enhancement of the [Smart] City and Spatial Enablement of Urban Population

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, following the previous definition, spatial enablement refers to the concept of location as a way to organize and manage spatial processes. Though in this context a spatially enabled society appears to be limited to governance, multi-purpose cadastre management, and land tenure and administration issues, its reality is broader in scope, and it theoretically includes a wide spectrum of users, as well as various levels of practices. At the same time, this theoretical broadness makes it unclear. Therefore, the concept of spatial enablement needs to be better defined. What does it mean really? What should a spatially enabled society be? And, to what extent spatial enablement could make smart cities more efficient?

Most recent definitions state that to be considered as spatially enabled, an organization (city, local Government, society), must first consider location and spatial information as common goods, and then make it available in order to stimulate innovation. To this effect, three necessary conditions are envisioned as necessary to become a spatially enabled society. First, citizens have to be "spatially literate". Secondly, spatial enablement requires “A conducive environment for sharing spatial data”, and this is essentially the aim of Spatial Data Infrastructures initiatives. Last but not least, there is no possible spatial enablement without globally unified Geospatial standards (Africa, 2011).

This third condition fits with the view of spatially enabled society as "dependent on the development of appropriate mechanisms to facilitate the delivery of data and services". But to be spatially enabled an organization has to: (1) accommodate in its very operational logic, a more effective and transparent political and electoral process by making relevant geographical information accessible to citizens; (2) foster economic market improvement through the development and diffusion of public geographical information products and services; and (3) allow monitoring environmental sustainability by using spatial indicators provided by distributed sensor networks (Rajabifard, 2009). Therefore there is a general agreement on the need for a "service-oriented infrastructure on which citizens and organizations can rely" to have access to geographical information and location-based services (Rajabifard *et al.,* 2003). Such infrastructure (basically close to the last generation of SDI) is seen as the key basis to any spatially enabled society, since it provides stakeholders with faster and direct information updating and downloading capabilities; and deploys mobile and monitoring applications offering augmented and virtual reality capabilities for instance (Uitermark *et al.,* 2010).

Furthermore, in a move towards a user-centric view of SDI, that is to say a more individual perspective of spatial enablement, it can be argued that SDI could contribute to a spatially enabled society. As such, users' preferences have to be taken into account within SDI, in order to increase user’s satisfaction and individual spatial enablement. Also, even if citizens do not necessarily need raw data, they need spatial information extracted from raw data, as well as location-aware or context-sensitive services providing access to the data that meet their interests and enhance their way of thinking by taking into account their spatial context. Furthermore, basic spatial knowledge can be used to improve data sharing and information retrieval processes (Abolghasem *et al.,* 2010).

Indeed, from a practical point of view, “spatial enablement” refers to the individuals’ ability to use any geospatial information and location technology as a means to improve their spatiality, that is to say, the way they interact with space and other individuals on/in/through space (Lussault, 2007). Hence, in the present social context, individual spatiality should not be considered detached from possibilities offered by information-enabled mobility (info-mobility), and real-time geo-communication (location-based communication). Therefore, we argue more fundamentally that a spatially enabled citizen is characterized by his ability to express, formalize, equip (technologically and cognitively), and of course consciously -or unconsciously- activate and efficiently use his spatial skills.

3.2 Spatial Skills Activation by Using Geospatial Technologies and Information

Spatiality refers to any individual or collective condition and practice related to the position - geographical location - of both individuals and groups relative to one another. It typically reflects the spatial actions achieved by individuals, social groups, or organizations (Lussault, 2007). In order to efficiently manage their spatiality and mobility, citizens tend to improve their spatial thinking capacities and use spatial skills. According to Lussault (2009), human spatiality is based on the five following basic spatial skills.

(1) Metrics skill refers to the ability to measure distances, and to distinguish the near and far using the Euclidean metric (measurement of distance in meters and kilometers), or in non-Euclidean metrics such as distance-time, distance-cost, distance-number of connections.

(2) Location skill is a matter of finding the "right" place and proper location to be or to do something, based on one’s context including the relative location of other objects, people and services.

(3) Scale skill refers to the capacity to put one’s actions in perspective; to compare different phenomenon or objects with regard to their spatial resolution or level of granularity; to discriminate the small and the big.

(4) Zoning skill refers to the ability to delineate areas and define the spatial limits of one’s actions, movements within space, and living or inhabiting the space.

(5) Crossing skill refers to the ability to cross through different kinds of barriers, obstacles, and security check-points, thresholds, etc.

Geospatial technologies and Location-based services offer users various direct and indirect ways to activate - and to some extend improve - their basic spatial skills. Nevertheless, availability and even use of such technologies does not necessary and directly imply spatial skill improvement, or, in other words, spatial enablement. As explained in section 2.2 above, the inherent tension between espoused technology (the way technology is pre-defined to work) and technology-in-use (the way that it will work in the context of its use) might seriously reduce the potential of geospatial technology regarding its contribution to users' spatial enablement.

Moreover, the pervasiveness of technology, the era of wikinomics, and the juxtaposition of physical and digital spaces, which represent characteristic factors in both the wikified and the Geo-localized world, transform human spatiality. Relation to space is no longer the same. Today, the digital and physical are so intertwined that an enabled citizen can just as much be fully "here" and “now”, as "there" and in the “past” or “future”. By this we mean that in a space resulting from a hybridization of the physical and the digital, the physical distance can be bridged by using telecommunication technologies allowing real-time transactions of digitally encoded messages between locations far apart from each other, while temporal distance is bridged by real-time access to memory of past events, thus providing people with tools to revisit the past or even to catch a glimpse of the future. Indeed, people can recognize patterns in the past through a certain number of algorithms, so as to be able to anticipate what is to come in the near future, or to predict the status of spatial systems in a far future. Whereas bridging physical distance is possible through telecommunication networks, the same process regarding temporal distance implies radical transformations as regard to how we collect, store and manage vast amount of information. Telecommunication technologies on the one hand, and memory collection, management and storage technologies on the other hand, not only drastically change the forms of human spatiality, but also the nature of spaces themselves. These new forms of spatiality are actually mostly co-spatialities. Co-spatiality refers to spatial actions people undertake to manage their relations with/in/through distant spaces and distant people mediated by technologies (Lussault, 2009). Managing co-spatiality requires individuals not only to mobilize the basic spatial skills mentioned above, but also to develop complementary skills, necessary for the adoption and use of geo-communication and location-based technologies. It particularly requires a new capability to connect to/disconnect to/ switch from one distant space and its occupants to another.

3.3 Info-mobility and Geo-communication Skills

In a spatially enabled society, with highly developed spatial skills as elaborated above, mobility is one of the key components of people's spatiality. It eliminates or reduces the operational or performative distance between social realities, and thus reduces remoteness by bridging places. Within “societies of mobile individuals” moving is no longer an end in itself, but a fully-fledged activity in which travelling routes, costs and times are optimized (Stock, 2005). For mobile citizens, the question is not so much

“Where am I?” as “What is around me?” (services, people, traffic, disturbances, shops…), “What can I expect?” and “How do I get there?”. To do so, individuals increasingly, and more and more systematically, use communication and information technologies (CIT), sensor-based networks and, more specifically geospatial-distributed technologies (Roche and Caron, 2009). As a consequence, mobility is enriched (increased) with dynamic information on the spatial location and environment (topology, social neighborhood, transportation schedules…) of users. This type of mobility, delivered to users through the mediation of technological artifacts such as GPS navigation devices, smart phones, and sensor-based networks, is referred to as “info-mobility”. It characterizes the interactions established between mobile individuals and the informational resources that guide and assist their orientational and navigational choices (Kauber, 2004; Sheller and Urry, 2006). These new spatial practice modalities, fitted with informational and communicational devices, mainly rely on the proliferation of Location-Based Services (LBS). These user-centered services “push” contextual information to users, that is to say information providing details about their location and context - characteristics of their environment, and also if necessary of their ongoing state of mind and specific objectives. They can be envisioned as pull services providing contextual information on demand. While the use of communicating mobile terminals (smart phones or personal navigation devices) is becoming commonplace, these tools are emerging as the key interfaces (mediators) of both the physical (real) and digital (virtual, partially intangible) space.

Geo-communication is indeed another related practice. Basically it refers to another skill developed by people to respond to the ubiquitous challenges they face. Geo-communication is communication between mobile individuals related to their place, supported and mediated by geo-communication technologies - arising from the convergence between mobile/telecommunication technologies and location-based technologies. For spatially enabled citizens, the use of geo-communication technologies is a way to project themselves into - to switch to - distant spaces and to establish communication with others from their remote position. This is actually a way for individuals to converge the "here" and "there", and thus to develop a quasi-capacity for ubiquity. Basically, this ability to disconnect from the "here" and to connect to the "there" is a way for spatially enabled citizens to compress space and reduce it to places where the Euclidean metric is no longer relevant. Each of these connected and augmented - with virtual and tangible information - places becomes a "space concentrate" from where the whole human space is accessible. Therefore, citizens' spatial enablement relates more to the linkage between explicit and tacit knowledge than just to spatial skills.

3.4 Converting Spatial Knowledge

Citizens' spatial literacy is a basic condition of spatial enablement as mentioned in section 3.1. This spatial literacy could not occur outside a recurrent learning process. An interesting description, as well as relevant to our study, of this learning process is based on the paradigm of knowledge conversion, which is achieved through socialization, externalization, combination and internalization (Nonaka and Takeuchi, 1995) (Figure 1):

- Socialization (tacit to tacit) is the process of learning by sharing experiences, thus creating tacit knowledge as shared mental models and professional skills (for instance, acquiring new understanding of the notion of place through informal exchanges of feelings with other members of a social network).

- Externalization (tacit to explicit) is the process of converting tacit knowledge into explicit knowledge (for instance making comments about a personal experience related to a specific location, and sharing them with members of a social network).

- Combination (explicit to explicit) is the process of enriching the existing explicit knowledge to produce new sets of knowledge (e.g. mashing-up forecast data with traffic data to feed an online transportation support system).

- Internalization (explicit to tacit) is the process of individual learning by repeatedly executing an activity using explicit knowledge (e.g. applying some travel recommendations, and using GPS navigation tricks as new personal tacit knowledge).

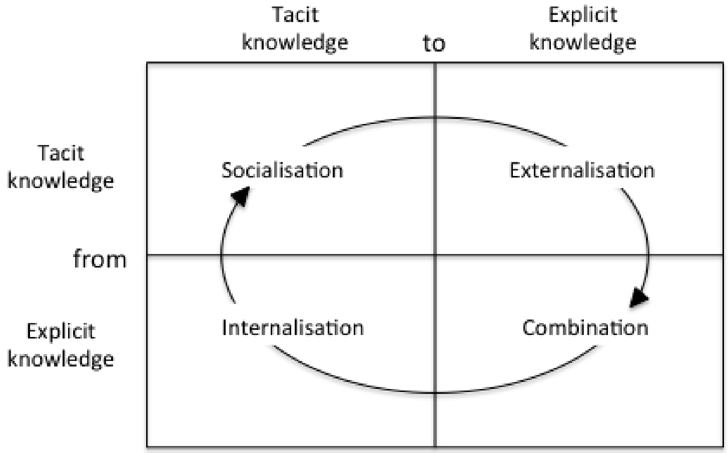

Figure 1. The knowledge conversion processes (from Nonaka and Takeuchi, 1995)

For these four modes of knowledge conversion social networking becomes central. In the context of a spatially enabled society, mobile location-based services can also support geo-spatial networking, whereas the device allows sharing location with others, exchanging information with others as well as navigating the physical and virtual space by searching for information. The capacity to share Geo-location with others through mobile devices along with social networking applications, and real time communication (phone calls, text messages, and video calls) transform the spatial and temporal modalities of exchanging and interacting with others, and consequently impact the spatial knowledge conversion processes by allowing for what can be defined as spatially enabled social networking.

In such a context, “Location-based Social Network” aims at locating contacts, notifying users of their proximity and allowing them to engage/disengage communication. This practice converts info-mobility and geo-communication into opportunities for social gatherings (InstaMapper, Google Latitude, Foursquare or Facebook Place for instance). A few services (e.g. Spotme) even mention the location of unknown individuals, according to the principle of linking ("matchmaking"). Combining the potentials of geo-location and social networking with real-time communication spatially enables citizens to mash up their (virtual) network with their (material) physical space, and then to share “real” experiences in the “virtual” world and vice versa. In such hybrid spaces, people can share, through different types of technological solutions, their successive locations and movements with members of their network, while tracking them in return. They can also enhance their geo-communication skills and enrich shared knowledge gained from "friend generated geographic content".

3.5 Spatially Enabled Citizens as Human Sensors to Feed SDI

User generated geographic content and geo-crowdsourcing are indeed two other major characteristics of a spatially enabled society as well as a smart city. Spatially enabled citizens increasingly use technology, particularly mobile technology, to voluntarily contribute and provide local information and share place-based knowledge on their networks. Users become both producers and consumers of this information. Citizens, as sensors, are able to provide their (social) network with real-time information about their spatial experiences: recording and sharing personal memories, reporting on inefficiencies and problem areas within the city, or rating the services provided in different locations. In this type of user-contribution-based service, community is shaped through LBS and, in return, these services rely on community, considered as a source of information. This concept of “citizens as sensors” (Goodchild, 2007) is also an important issue for Spatial Data Infrastructures (SDIs). Spatially enabled citizens could be considered as a dynamic source of information to feed the SDI data flows, (Craglia, 2007) as well as the monitoring system of smart cities.

If citizens can unconsciously provide useful information to fuel smart city (when their traces, their spatial behaviors, or even their tweets for instance are tracked and analyzed to better understand new dynamics in the city) they also can consciously participate to city life and actuation. Similarly, in the context of spatial enablement citizens could take advantage of existing Spatial Data Infrastructures while creating and sharing spatial knowledge, as sensors in their own right. To this effect, volunteered Geographical Information (VGI) becomes the most prolific source of information to characterize places.

As we saw previously, spatially enabled society and smart cities have much in common, and they both benefit from Spatial Data Infrastructures as enabling platforms improving access, sharing and integrating spatial data and services. Yet they are still conceptual and technical challenges remain to achieve a fully functional system (Rajabifard, 2009). A smart city as an actuating source of spatial enablement might possibly provide solutions to overcome these challenges. In the following sections we seek to provide thoughts and ideas to move forward to this direction.

4. An Ontology of Spatially Enabling Smart City Technologies

In the context of smart cities, spatial enablement particularly refers to the capacities that add functional depth to the space of a city via a series of technologically enhanced transformations of spatial practices.

First of all, bridging the distance between individuals and different locations is the key feature of smart cities. Material and human resources travel through the space of the city in a streamlined manner, using different mobility technologies, the efficiency of which is maximized by a constant regulation of the system through real-time monitoring. At the same time the city has become a heavily networked space, so as to allow multiple-bridging to connect disseminated locations. Telecommunication networks represent a major bridging tool, enabling real-time exchange of digitally coded messages, with a higher than ever resolution and multi-modal formats (textual, audio, video transmission, etc.).

Secondly, building on the capabilities offered by both bridging technologies and those accommodating on-line social networking (boosting/fostering social organization), new dispersed communities emerge, as well as new associations between their members. These on-line, geographically remote communities develop ties with each of their members. Sometimes, these ties are stronger than place-based ties established between members of communities living in the very same location.

Third, the technologies of memory retrieval and management have given us the prospect of a world of “total recall” (Bell and Gemmel, 2009) where nothing is forgotten and the digitized log of any occurrence is at hand anywhere and anytime. This means that what we can access defines our very being.[1] Take the practice of

[1] *MyLifeBits* is a Microsoft research initiative looking at the prospect of a digitally implemented total memory. The project is a decade-long effort to digitally record everything in computer-science researcher Gordon Bell's life including what he did, saw, read, ate, and felt. Basically, the project examines the possibility of creating a total memory of a given subject's life experience.

taking photographic pictures as an example. In its pre-digital version, someone would use photography to keep record of his/her life experience as a series of stand-alone memory objects; that is, photographs. Then, photographs would be taken, developed on paper, stored in albums and boxes, disconnected from the world, and would eventually decay and disappear due to the degenerative impact of time on all material things. Once the practice was digitized, the pictures would acquire a theoretically eternal dimension: since they were not stored as material objects, they would not decay, and they could be now searched, retrieved on-demand and cross associated with other forms of information. With the introduction of on-line social networking platforms and user-generated content, stand-alone digitized personal memories were gradually aggregated to a comprehensive, collaborative, ever growing database of human living memory. Once cross-associated with their temporal, geographical and social context, they have become an extremely powerful tool to describe our environment. This condition is ubiquitous across many other practices as well. Our capacity to collect, store and manage huge amounts of data has allowed us to maintain log files from many day-to-day activities that are mediated through digital and telecommunication technologies. Every time a phone call is made, a credit card is used, a text message or an email is sent, a Google query is submitted, a Facebook profile is updated, a photo is uploaded or tagged on Flickr, or a purchase is made on a major on-line mega store such as Amazon.com, an entry with the time and location of this action is added to a dataset on a central server (on the cloud) administered and maintained by the organizational entity providing the platform for these, and hundreds of other day-to-day operations. This huge amount of data is really changing the relationship that we have with information and with our information-rich environment. This change represents a driving force for ICT-driven solutions to urban problems in smart cities.

Fourth, while memory-retrieval and management technologies give us the prospect of a world of “total recall,” where nothing is forgotten and the digitized log of any occurrence is at hand anywhere and anytime, the post-human factor is also added to this mix. Consequently, using mobile technologies extends each individual digitally by providing him or her with a mini-computer equipped with a plethora of embedded sensors, and a small portal for the delivery of information. Such a device is capable of establishing a data connection both to the infrastructure of mobile networks, and to the more localized, ad hoc networks that are of a peer-to-peer nature. This gives us a Pandora world of hyper-connection; as fantasized in the 2009 movie *Avatar*, where everything and everybody can be connected to everything and everybody else through space and time, and the connection can be fostered by hierarchical infrastructures such as cellular networks, or peer-to-peer ad hoc networks mediated through Wi-Fi and Bluetooth technologies.

Fifth, memory and data-retrieval technologies allow bridging the temporal distance between incidents, and to provide access to the hybridized universe whenever it is needed. Wired and wireless communication technologies allow bridging the physical distance between incidents, so that the analog world, translated into digital format, can travel through space and provide users with access to the hybridized universe wherever it is needed. However, we still have a missing link here. Real-time data reception and transmission technologies enable data-scapes to take form based on networked entities. Yet, in order to achieve a thoroughly hybrid, spatio-temporal phenomena, the information layer needs to be situated within the physical world. The series of binary 0s and 1s must to be attached to the actual, global locations they represent via sensed data. Entities that populate the physical world and their digital counterparts in the virtual layer, that is data about them, need to be cross-referenced. Technologies of geo-localization allow us to locate digital content within the physical realm by annotating a given geographical location with data, or cross-referencing data with a geographical location. This makes it possible to envision two different but connected typologies of information-rich geographies in the context of smart cities, where the urban landscape is conceived as the cradle of real-time relevant information regarding urban processes. In what we define as real-time localities, the virtual representation of space is the interface through which information is acquired and delivered. It is similar to a dynamic, interactive Google map that is populated with placeholders of various real-time information, and accessed by a sedentary user behind a computer screen. In what we identify as geo-taggable/geo-cacheable spaces, the physical space itself becomes the interface for the acquisition and delivery of digital content. Agents dynamically geo-tag and geo-cache information based on their real-time locations. This is the case for almost all location-based services that users gain access to via their smart phones, while on the run and navigating the city.

In short, the capacity to have real-time access to distant locations and/or to those who inhabit or occupy these locations using the services offered by wireless or wired tele-communication networks, as well as the capacity of being accessible via the same networks, the capacity to annotate space with digital information, and the capacity to access annotations based on the real-time location of the user who is seeking to retrieve contextual information in a digitally annotated space, all of this will provide us with a basis for a working ontology of spatially enabling technologies-in-use.

To illustrate our ontology at work, we can use three projects by MIT SENSEable City Lab that we believe are relevant examples of how a technology-at-work will empower and spatially enable the urban population, and hence contribute to smartening the city they inhabit:

(1) CO2GO is an iPhone applet that makes use of the embedded sensors of the device (accelerometer, GPS, etc.), and deploys a context-aware algorithm to calculate in real-time the carbon emissions of the user, by automatically detecting his/her transportation modes and tracking the distance covered. This information assists users in making smarter individual transportation choices to collectively reduce carbon emissions in cities. This smart solution is built on the citizens' vision as sensors of the processes contained within the smart cities on

one hand, and the citizens' spatial enablement via social networks on the other hand.[1]

Figure 2. CO2GO Screen shots of Mobile Application, MIT SENSEable City Lab ©

(2) Aida (Affective Intelligent Driving Agent) is a smart navigation system aiming at estimating a driver's likely destination based on collective mobility patterns in the city and individual profile information - such as past riding behavior and online calendar entries - and providing relevant information to the driver accordingly. In order to deliver this information, Aida's interface brings the virtual augmented map closer to the actual physical city seen through the windshield. This is achieved by incorporating the unused area on the dashboard to establish a direct and seamless connection between the actual street and its representation on the digital map. The project is very much in line with the improvement of navigation-related spatial skills using geographical information and techniques for annotating spaces with digital information discussed in this paper.[2]

[1] For more information on the project please consult its dedicated web entry at http://senseable.mit.edu/co2go/

[2] For more information on the project please consult its dedicated web entry at http://senseable.mit.edu/aida2/

Figure 3. AIDA interaction scenario on the digitally augmented dashboard to retrieve location-aware information while driving, MIT SENSEable City Lab ©

(3) Copenhagen Wheel which retrofits a conventional bicycle and transforms it into a mobile sensing device. Controlled by the cyclist's smart phone, as he/she cycles, the wheel's sensing unit captures his effort level and information about his/her surroundings, including road conditions, carbon monoxide, NOx, noise, ambient temperature and relative humidity. The cyclist can also share this data with friends, or with his/her city – anonymously - and contribute to a fine-grained database of environmental information that then can be accessed through a phone or the web. Again, the project is apparently built on the potential offered both by embedded sensors to crowdsource the process of collecting geo-referenced information regarding the city and social networks to disseminate this information and democratize access to it.[1]

Figure 4. Copenhagen Wheel and its embedded technologies, MIT SENSEable City Lab ©

[1] For more information on the project please consult its dedicated web entry at http://senseable.mit.edu/copenhagenwheel/

Figure 5. Copenhagen Wheel retrofitting a conventional bicycle, MIT SENSEable City Lab©

Figure 6. Copenhagen Wheel screen shot of mobile social network applet for sharing collected information MIT SENSEable City Lab ©

These three projects, and others within the same field that considers the deployment of sensors, networks and location technologies to empower the urban population in their day-to-day lives, add a technologically enhanced performative and functional depth to the city.

5. Conclusions

In smart cities that are reliant on ICT-driven solutions to address urban problems on one hand and to spatially enable citizens on the other hand, urbanity merges with digital information so that the built environment is dynamically sensed and synchronously actuated to perform more efficiently, intelligently, and sustainably. Under such circumstances geographical information systems, in combination with telecommunication networks that provide access to real-time information on these systems, as well as for place-based or context-aware social networking, blur the distinction between “here” and “there”and between “present”, “past” and, “future”. Bridging the spatial and temporal distance is a contributing factor to the spatial enablement of the citizens of smart cities in the near future. Perhaps a future research direction should concentrate on the ability to blur these distinctions to contribute to the smart cities’ agenda? Why and how this empowers people to tackle challenges they face in urban planning and management? To what extent these tasks can be crowd-sourced to a spatially enabled, technologically aware population, capitalizing on informal competences of citizens as opposed to limiting the realm of production of space or spatial knowledge to a limited team of experts? How SDI could contribute to smartening up cities in the context of spatial enablement? And in return, how spatially enabled citizens could contribute to the smart city?

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