Sensing Places' Life to make City Smarter

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ABSTRACT
This paper explores the smart city concept and proposes an innovative way of sensing urban places' life using aggregation of devices sensors (cameras…) and human sensors (VGI, geosocial networks) datasets. The paper also discusses the need of an enabling geospatial information platform to facilitate data discovery and access in order to support smart cities' operations. Indeed, in this context, Spatial Data Infrastructure plays an important role and acts as an enabling platform linking governments authoritative spatial information with crowd sourced, voluntary information initiatives.

Categories and Subject Descriptors
- Urban sensing and city dynamics sensing
- Smart recommendations in urban spaces
See also http://www.acm.org/class/1998/

General Terms
Measurement, Design, Security, Human Factors.

Keywords
Smart city, sensors, place, spatial enablement, Volunteer Geographic Information, crowdsourcing, enabling platform, SDI.

1. INTRODUCTION
Our living world becomes more and more complex every day and faces growing challenges. Urban areas are especially under pressure, as their population will exponentially grow in the coming decades. Various economical, environmental, social, demographical, etc. issues and stakes will lie ahead in the near future. These issues are even stronger while the age of real-time and location-aware information accelerates social and spatial changes. Building "smarter" (intelligent) urban environments and communities is one of the potential solutions that is currently proposed and explored to tackle these challenges.

Smart City is one the most fashionable answers that was firstly proposed, and has been used as a marketing artefact by companies like IBM (Smarter Planet initiative), CISCO (Smart+Connected Communities division) or last but not least and more recently Intel (Collaborative Research Institute for Sustainable Connected Cities), and also by some of the biggest cities in the world (Rio de Janeiro, Singapore, London…). A smart city is roughly described as a platform or a system of systems, essentially based on three components: Sensors, Networks and Engagement (actuators).

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But is this 'Smart Cities' approach makes cities smart enough to meet the current and future challenges? The answer is certainly NO [1], but it s not obvious. Making a city smarter is neither only a technological infrastructure issue, nor a managerial one. It is also and essentially providing citizens a better and safer way of living in urban areas, in the places where they live, work, have fun, consume… Therefore, sensing life in those places is a major stake to understand new city dynamics and then to design better living urban environments. The Singapore Live project running by the MIT SENSeable City Lab. is a good example of such a stake.

With the many challenges facing society today at multiple scales, location has emerged as a key facilitator in decision-making. Location data is now commonly regarded as the fourth driver in the decision-making process. The location provides more intelligent data analysis due to improved analytical and visualisation capabilities. Location-based services and information are the basic components needed to dynamically describe and represent places' life [2]. We live in the Global Location Age. "'Where am I?' is being replaced by, 'Where am I in relation to everything else?'" [3]. Indeed with the exponential growing of location-based social networks (geosocial), Geoweb 2.0 and geoinformation crowdsourcing, citizens are increasingly involved in the production of geographic information. This kind of information, voluntarily produced and diffused by people, mainly refers to the places they live/use. Indeed, people whom live in a place are often the "experts" of this place [4]. The active engagement of citizens is then a major requirement for smarter operations of a city, and this needs for citizens to be spatially (digitally) enable [1]. Capturing the sense of places is then a major stake for urban communities that look for a smarter way of development. Smart city infrastructure has to be based on an Enabled platform for aggregating formal data sensed by device sensors and sensible knowledge sensed by citizen sensors.

This stake also poses fundamental research problems: How to efficiently and dynamically senses urban places' life? What kind of mechanisms should be developed to actively engage citizens as active sensors? What should be included in a Volunteer Geographic Service – VGS to make this service useful for engaging citizens in smarter city operations?

This paper precisely aims at providing recommendations for sensing urban places' life by using aggregation of devices sensors

(cameras…) and human sensors (VGI, geosocial networks) location-based data. It also discusses the data infrastructure that is needed to facilitate data access, discovery and linkages. Section 2 provides a brief overview of smart city challenges, and especially argues that a city could not be smart without spatially enabled citizens. Section 3 discusses what the concept of Place does really mean in the smart city context, and to what extent place does matter to make city smarter. Section 4 finally develops the proposed methodology, based on a work in progress, for sensing places' life in smart city, and provides example applications (e.g. crisis management).

2. HOW TO MAKE CITY SMARTER?

2.1 Smart city weaknesses

A recent Wired.uk.co paper entitled "Surely there's a smarter approach to smart cities ?" [5] provides a really good overview of the weaknesses of current smart city deployment. Based on the analysis of the IBM and Cisco's projects, this paper concludes that this approaches are weak. The main weaknesses (this is not exhaustive) are the followings:

- These smart city approaches are to much technologically driven and mainly reflect the most basic functionalities of the Internet of Things,
- These are based on a "One-size fits all" and very top-down strategic approach "to sustainability, citizen well-being and economic development",
- The 'smartness' is limited to efficiency and there is most of the time nothing really develop to improve and increase the flexibility and adaptability of the city's operations,
- Citizens are not really considered in these projects, except as passive sensors (for instance by unconsciously providing their location through their smart-phone activities),
- These initiatives are not really scalable, only small scale is really taken into account, and city is considered as an indivisible whole, as a single coherent and predictable unit.

2.2 Smart city requirements

The Latin etymology of intelligent ("intelligentare") refers to the ability to learn about/from someone or something, understand, interact with one's environment and, act relevantly. This ability particularly consists of adaptability to changes in the environment and, capacity for knowledge from this environment.

Then "smart city" refers to the capability of a city (or a community) to understand events or phenomena that characterized its internal and external dynamics (crisis, transport issues, road traffic, socio-economical transformations, demographical changes, etc.).

Moreover, in the current hypermodern context, a smart city must also be able to identify the main components of an event (where, when, who, what, how), to analyze it, to provide location-aware (and contextual) sense to it and, to react (actuate) properly (and in real-time – at least compliant with the nature of this event).

In order to achieve these goals, urban infrastructures (transport, communication, water supply or energy...) have of course to be redesigned and upgraded by articulating their material components with existing capabilities of new active and communicant sensors and actuators. This refers to the Web 4.0, the Internet of Things, the Web of communicating objects.

But this also requires the cities' capacities of analysis, diagnosis and communication to be substantially and significantly improved. This requirement is very much in line with the issue of "big data" that increasingly grows while data coming from various sensors are multiplied and accumulate. This refers to the Web 3.0, the semantic web, this of meaning, of sense, of signs.

Last but not least, urban society that is to say citizens, institutional organizations, public-private stakeholders also have to develop or increase (new) adhoc skills to act in this smart urban environment. It must negotiate new rules to work all together, new modes of opened governance, adapted contribution mechanisms (as crowdsourcing), new way of participation. This refers to the Web 2.0, the participatory geoweb [6], this of geosocial, user generated contents, participation, social networks and open data.

Major issues also arise as regard as citizens' digital and spatial literacy. This active and engaged citizen (see section 3.2) is indeed the main driving force of a "smart city". The growing amount of location-based contents generated by connected - anytime and anywhere - user (citizens' produsers equipped with smart phones) ; the exponential growth of volunteered geographic information (Foursquare: 20 million users and 2 billion check-ins) trough social networks (most of which are Location-Based social networks) become the basic features of the Spatially enabled society. This is defined as 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" [7].

From a practical point of view, and in the smart city context, "spatial enablement" refers to the individuals' (or collective) 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. Spatiality is the dynamic component of place making.

Therefore, more fundamentally 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.

Smart urban solutions have to be built on the vision of citizens as active sensors on one hand and on spatial enablement of citizens via social networks on the other hand. These solutions have to be inline with improvement of navigation related spatial skills using geographical information and techniques for annotating spaces with digital information. These kind of solutions have also to be built on the potentials offered both by embedded sensors to crowdsource the process of collecting geo-referenced information about places in the city and social networks to disseminate this information and democratize access to it.

3. MORE PLACES, LESS SPACE

3.1 Back to the concept of Place

In this section we argue that places, and sensing urban place especially, are central as a way to understand cities and then to smartening its urban management and design. But what the concept of Place does really mean in the smart city context, and to what extent place does matter to make city smarter?

Place has different meaning depending on the field of interest. As mentioned by Mike Goodchild [8] "*The concept of place has a long history in geography and related disciplines, but has been plagued by a fundamental vagueness of definition*". From a social perspective, Place is considered as "an expression of context", an expression of the "value of linking individual behavior to context" [8]. Place is often used in the sense of community or

neighbourhood, implying an informal relationship to an area surrounding the individual's place of residence [8].

From a more geographical point of view, Michel Lussault [9] argues, "spaces are socially constructed"; and all space is a formal arrangement of artefacts, materials and ideas, and is characterized by specific attributes like scale, metric, substance and configuration. He considers space as a meta-concept that is contextually and contingency shaped as places, areas (territories) or networks. In this framework, place are space where Euclidian / metric distance doesn't matter.

The concept of place does not certainly mean the same in the location age context than it meant before. However the potential of location-based technologies is not limited to the ability to say "where" we are or "who" and "what" are close to us. It could also provide extended capabilities to users, such as accessing new forms of virtual spaces or increasing physical space in which they live (by adding digitals artefacts for instance). A sort of "informational thickening" of places and networks (already identified in the seminal book of Mitchel [10], appears from these new practices. This hypermodern urban contexts and spatially enabled society are indeed characterized by its wikinomics [11], where places of interest could be identified, sensed and characterized by citizen seen as sensors (geosocial 2.0).

For Manuel Castells [12], this new form of location-based social networks characterizes the Society of Flows. Castells said "*Time and Space do not disappear but they are transformed*", one individual could possibly be in two different spaces in the same time, people constantly evolve in overlapped multifunctional networks. Then, places become multifunctional and multi-meaningful. Castells finally argues, "*The space of flows dominates the space of places*".

3.2 Does Place still matter for smart city?

As it was highlighted before, people increasingly live in high-density urban, often high rise and multi functional buildings. These increasingly urbanised populations will predominantly live in multi-level, multi-purpose, highly engineered, high-rise developments. Cities require significant infrastructure above and below the ground. Rapidly expanding vertical cities and their populations will experience a range of new environmental, social and economic challenges. With this in mind, then the question would be, does place still matter in a spatially enabled society? Contrary to the Castells' arguments, we believe the answer is undoubtedly yes. But it's not obvious, and the reality more complex than a simple tension between place and flow.

While concepts of place and network are becoming central in the "spatially enabled society", the relevance of the concept of territory (space-area) is under erosion. Geographers conceive territories as areas, which are sensitive to Euclidian distances, bounded by identifiable and clear boundaries, and characterized by continuous components and phenomena. Most of those territories gradually disappear. In the same time, networked places, characterized by a spatial and temporal discontinuity of their embodied components become preeminent. In this context of hyper-modernity, places become hyper-places where physical Euclidean distances do not still relevant, but in which other forms of distance (time, connectivity, digital, social...) structure social relationships and human spatiality.

Our daily living spaces may not be reduced to a horizontal layer, physically accessible. Instead, "virtual information" that are mixed (mashed-up) are fully part of its. This ability to choose to live into (with) places, essentially hybrid, in their informational thickness, allows individuals to precisely "be fully in their world". Spatiality in this context is essentially based on co-spatiality. This capacity for engagement / disengagement (for navigation through the entire informational thickness of places), is actually part of all spatial actions undertaken by individuals, and in this sense refers probably to a new type of spatial skills that should be analyzed.

Further, in the context of cities, the lack of an efficient and effective three dimensional solution limits the ability of the public to visualize and communicate 3D developments, the ability of architects, engineers and developers to capitalize on the full potential of 3D city models; the ability of governments and developers to visualize multi-level developments resulting in increased costs and delays; and the ability of land registries to administer a title registration system that can accommodate these increasingly complex multi-level developments.

Having said that, in the general context of geocommunication (communication based on location and mobility), places and then (by linking) networks become the preeminent forms of space (much more than area). More precisely, the construction of spaces is mainly based on the aggregation of places; those aggregations are more or less organized, more or less sustainable. Those places may refer to temporal sequences of positions (location + relations) of one mobile and communicant individual, which together generate a space-network (formalizing a "route"). But they can also refer to locations (in a given time) of various individuals, all connected, all members of a "social network", and in this case space contextually formalizes the social network. It can finally be a hybridization of the first two, that is to say dynamic space-networks, based on the tangled routes and crossings of the members of a given social network. In very rare cases, places become territories with fuzzy and shifting boundaries. Then these space-areas formalize the spatial extent of the interactions occurred between the members of a social network.

Spontaneous and localized contributions of individuals (localized tweets, Facebook Places or foursquare chek-in) are most often materialized by Points of Interest (POI). This POI could be considered as new forms of spatial projections of social relationships and human spatiality. These contributions raised through mobile technologies, but accessible from different platforms (Internet, PDAs...), act as socio-spatial mediators, in charge of telling where people are, what they are doing, with whom, what they have in mind, who and what are there with us (or around, close to us), what they expect from others, what they think about the place, etc. [13]. These contributions are emerging as an essential way to access the sense of places. Every place tells a story, and user contributions are its more relevant medium.

Due to the relative pre-eminence of place to understand urban environment, and following Mike Goodchild [14] idea, it is time to move from a space-based to a place-based geospatial infrastructure. This is what the following section is about.

4. SENSING PLACES' LIFE

4.1 SDI as an Enabling Platform

Spatial Data Infrastructure (SDI) is an integrated, multi-levelled hierarchy of interconnected SDI based on partnerships at corporate, local, state/provincial, national, regional (multi-national) and global levels. This enables users to save resources, time and effort when trying to acquire new datasets by avoiding duplication of expenses associated with the generation and maintenance of data and their integration with other datasets. SDIs

are increasingly focussing on large scale people relevant data (land parcel based data or build environmental data) with the result that today it is suggested most SDI activity worldwide is at this level. A central aspect in understanding these developments is the evolution of mapping, and the growth of land administration systems and national mapping initiatives in different countries.

Data Infrastructures are now in place that enables individuals to position themselves and navigate to a chosen destination by multiple routes, identifying nearby places and services of interest. In this context, SDI and spatial technologies are now used routinely in decision making to support city planning and forecasting and at the same time to address some of the world's most pressing societal problems. Many countries now recognize SDI as an essential modern infrastructure such as information communication technology (ICT), electricity or transportation.

Harlan Onsrud [15] defined SDI as a network-based solution to provide easy, consistent, and effective access to geographic information and services to improve decision making in the real world in which we live and interact.

Spatially enabled society is "dependent on the development of appropriate mechanisms to facilitate the delivery of data and services". 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 [16]. 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 [17]. 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 [18].

4.2 Citizens as sensors

User generated geographic content and geo-crowdourcing are indeed two other major characteristics of spatially enabled society as well as 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" [19] 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 [20], 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. Several urban computing projects using human (e.g. drivers or vehicles) as sensors, have already demonstrated to what extent this kind of bottom up approaches, could provide city decision/policy makers useful and relevant information about city life [21, 22]. Similarly, in the context of spatial enablement citizens could take advantage of existing Spatial Data Infrastructures -SDI- while creating and sharing spatial knowledge, as sensors in their own right. To this effect, volunteered Geographical Information -VGI- becomes the most prolific sources of information to characterize places. Based on both such SDI resources and their own local knowledge, citizens as sensors, could not only provides place-based information, but also Volunteered Geographical Services – VGS, and then make them more and more engaged as active smart city actuator [23].

As we saw previously, spatially enabled society and smart cities have a lot 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 to achieve a fully functional system [16]. Smart city as actuating source of spatial enablement might probably provide solutions to overcome these challenges.

4.3 Cameras sensors

Distributed cameras across cities which are used for many applications such as traffic management, or public safety can also be useful for other potential applications. These cameras can be considered as sensors network for further data collection and analysis for live city application of related movement and planning or other related areas. With this in mind, this research aims to integrate imagery from the city's camera sensor network to create an immersive and coherent 3D visualisation of streets and their real-time dynamics and events. The camera sensor network will include live cameras around the city, traffic control sensors and VGI. High-level image processing, including feature extraction from live video streaming, will allow for accurate and detailed information to be readily available in real-time. A dynamic live city has applications as diverse as urban planning, disaster management, asset management and intelligent transportation systems.

In addition, recent advancement in digital imaging and computing technologies allows for efficient image analysis for 3D object reconstruction. Meanwhile, video technologies are pursued for analysis of dynamic scenes, moving object detection and tracking. In this project, we will further explore vision technology to fuse the static virtual city with temporal information such as the movement of pedestrians and cars obtained from videos.

4.4 Aggregation

In order to aggregate place-based information in a dynamic way and to ensure traceability capability, we propose an enabling urban platform based on a WikiGIS framework. The WikiGIS applies wiki management and integration strategies to geo-data–geometry (shape and location)–graphic attributes–descriptive attributes, and not solely to location-based texts, as in geoblogs for instance. More precisely, a WikiGIS is a geographic information system (GIS), created online (on the Internet) through collective interventions (in this case, data coming from camera-sensors together with data coming from citizens), which involves interactions between participants, followed by the combination and traceability of their contributions into coherent geospatial representations that are open to improvements [24].

In this context, a potential application will be an experiment system which delivers live city allowing for visualizing the dynamics and movement in the city, thus, stimulating visual-based thinking, space perception, and imagination. Spatially distributed live events can be observed on the live city, just as on the spot. Such spatially enabled live events in the context of virtual city scenes facilitate enhanced comprehension of objects, events and patterns, in relation with incidents in the nearby streets. Further, to support this idea, a component also would be to develop a holistic decision-support system and a smart Spatial Platform for city management, in particular in the context of disaster response, and recovery. The urban disaster integrated decision-support system will provide a dashboard for the strategic, tactical, and operational decisions arising during disaster response. This system will enhance the cognitive abilities of decision makers, allowing them to explore multiple scenarios in parallel, to visualize the consequences of their decisions under various assumptions, to refine the decisions continuously over time.

Spatial data is often heterogeneous and distributed in networks as it might be created by city's inhabitants, government or private sectors using different techniques, existing IT systems and readings form the physical environment [25, 26]. In addition, spatial data require interpretation to be relevant in emergency situations. In an emergency situation, geospatial data should be brought together from different sources, integrated in homogenous formats and, analysed and converted to momentous information. Currently such a workflow is not automatic and requires a substantial input by an individual, which is often not effective in emergency response scenarios.

The aim of this experiment is to develop and implement a smart spatial platform that provides access to multiple distributed data sources (including data from cameras and live inputs) automatically integrates geospatial data, intelligently analyses data and generates user friendly information to support decision making. The proposed platform consists of four main components as illustrated in following Figure.

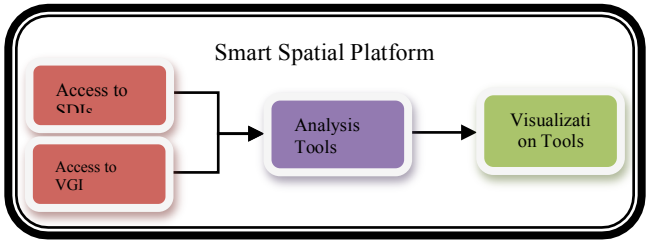

Figure 1. Smart Spatial Platform.

The first component is access to SDI which provides spatial data from different sources. SDI provides access mechanism for the smart platform to connect and download data from distributed sources. The SDI also provides a standard access method such as internationally compliant web service approaches.

The second component is access to VGI. This is the spatial data that are crowed sourced. The third component is the analysis tool that uses optimized models that can replace the human modelling skill and knowledge for decision making such as planning or disaster management. It includes in particular a VGS for validating VGI data, based on comparison algorithm and diff. operators (data triangulation) using SDI data and physical space description (sensed by cameras) as references to elaborate geographical rules [27]. The fourth component is the information visualization tool. It provides analyzed data in a user-friendly and intuitive manner, both in 3D (cameras sensors) and 2D, so the data can be effectively used in different situations.

5. CONCLUSION

This paper proposes a place-based urban platform that aims to facilitate data access, discovery and linkages in a smart city context. This wiki-platform is fed both by camera-sensors information and citizen-sensors trough their location-based network. By sensing urban places' life, this platform contributes to the smart operations of cities.

The work related in this paper is a work in progress. The platform is currently under development and an experimental protocol should be designed and applied to urban crisis management by the end of this summer. This paper provides illustrations of how to proceed to move urban infrastructures and city components towards smarter operational modes. Geospatial technologies, information and methods are powerful means to smartening the world by providing multi-sensing capabilities, building models, improving analyses and capacities to understand and react by feeding actuating technologies or engaged people.

But more important for a smart city is its capability to capture the sense of places. A city is not a machine, but rather made by people local actions and feeling. This could not be captured and represented without active citizens sensors (VGI, crowdsourcing…) connected to location based-social networks.

Capturing the sense of places, in a dynamic and 3D way, is then a major stake for urban communities that look for a smarter way of development. Smart city infrastructure has to be based on an Enabled platform for aggregating formal data sensed by device sensors and sensible knowledge sensed by citizen sensors.

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