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## Special Issue on Smart Applications for Smart Cities – New Approaches to Innovation: Guest Editors' Introduction

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Cities are complex, networked and continuously changing social ecosystems, shaped and transformed through the interaction of different interests and ambitions. Employment, sustainable development, inclusion, security and quality of life are important concerns and in this respect many cities are confronted with a wide range of challenges. Cities, particularly in rural areas, are also facing the implications of ageing population in combination with economic decline [9]. However cities also represent a promise for the future: a vision of freedom, creativity, opportunity and prosperity [4]. More than half of the global population is now urban and projections estimate that this percentage will even grow towards 70 % in 2050 [13]. At the same time, technology is currently promoting unprecedented changes in urban areas, which are often labelled as *smart city* developments. Internet-based infrastructures of cities, addressing the above mentioned concerns, comprise a diversity of services in areas such as healthcare, energy, education, environmental management, transportation and mobility, and public safety. These services are increasingly enabled by broadband infrastructures, wireless sensor networks, Internet-based networked applications, open data and open platforms. Over the past decade digital technologies have begun to blanket our cities, working together to form the backbone of a large, intelligent infrastructure. Broadband fibre-optic and wireless telecommunications grids are supporting mobile phones, smart phones and tablets that are increasingly affordable. At the same time, open databases - especially about government - that people can read and add to are revealing all sorts of information, and public kiosks and displays in buildings are allowing literate and illiterate people to access information. Add to this foundation a relentlessly growing network of sensors and digital control technologies such as smart meters, all tied together by cheap, powerful computers and our cities are quickly becoming like *computers in open air*.

Against this background, this Special Issue addresses the role of smart applications in cities, especially inasmuch they foster enhanced living and working conditions, new modes of participation and a higher level of engagement of citizens. In this issue we also aim to explore the process of innovating smart applications and how it is intertwined with urban development itself.

### Smarter Cities

The concept of *smart cities* has emerged during the last few years to describe how investments in human and social capital and modern ICT infrastructure and e-services fuel sustainable growth and quality of life, enabled by a wise management of natural resources and through participative government [2]. Many of these aspects come from increased knowledge of our urban environment, which can now be sensed to an unprecedented extent. First, there is sensing via existing systems. The idea is that we can use the great wealth of digital fingerprints that are collected by networks of various nature (telecommunication networks such as cell phone and landline, banking networks, social networks etc.) to better understand the city. These datasets, if spatially and temporally cross-associated, become invaluable sources of information about the dynamics of the city. Aside from tapping into existing networks, customized sensor networks can also be implemented to extract large amounts of information about the processes contained within the built environment and channel them to a central control and command mechanism. Furthermore, instead of the previous top-down approaches, we should also consider more grassroots, bottom-up processes for sensing the dynamics of cities based on the participation of citizens, companies and organisations. One possibility is thinking of each citizen as an agent for sensing and reporting his or her individual experience through tapping into data generated by user-contributed content on content-sharing platforms – something that we could call crowd sensing.

Against this backdrop, this issue argues that truly smart cities are driven bottom up by citizens and organizations rather than by top down visions and plans that ignore the innovative potential of grassroots efforts, while governments should play the role of mediator bringing companies, research organizations and creative people to work in concert (see [11]). This perspective leads to a multi-dimensional smart city concept: it is a future scenario (what to achieve), but even more it is an urban development strategy (how to achieve it). It focuses on how information and communication technologies enhance the lives of citizens. This should not be interpreted as drawing the smart city technology scenario. Rather, the smart city could be about how *people are empowered*, through using technology, to shape urban change and realizing their ambitions. The smart city provides the conditions and resources for change. In this sense, the smart city is an urban innovation ecosystem, a living laboratory acting as *agent of change*.

The concept of Living Labs (see e.g. [1], and in relation to smart cities [12]), which is explored in several of the papers presented here, takes its point of departure in the consideration of people as innovators [14], and envisions environments of open and user driven innovation. Now that infrastructures and social networks become more advanced and widespread, the role of the Internet as an enabler of collaboration and city services has become more important for urban development. Cities nowadays have a critical role as drivers of innovation, a trend that is even intensifying as more people and devices are becoming part of the Internet landscape. Cities are becoming a living lab itself, a playground of innovation and transformation, which is exemplified by the emerging new ways of collecting and using urban data. The connection between smart environments and bottom-up innovation practices in the framework of cities and urban agglomerations is the main focus of the Special Issue. In particular we explore how collaboration platforms, embedded systems, open data, and semantic web technologies sustain new cycles of innovation driven by the creativity of the population and the collective intelligence of collaboration.

## Smart City Applications

The meaning of *smart city applications*, which is central to this special issue, needs some clarification. Smart applications are defined here as pieces of software (such as apps) that empower a group of actors (city, community, citizens) to collaboratively address city challenges in more efficient and intelligent (*smart*) ways. This definition does not include all possible smart city applications, which could also be based on the deployment of new types of digital hardware in the city but will be followed for what is discussed hereinafter. From this perspective, from all apps, some are for cities enabling collaboration and various forms of co-activity, and some of them are *smart* enabling more efficient solutions to city challenges of growth, inclusion and sustainability. Software–collaboration–efficiency, taken together, makes the constituting property of smart city applications and precondition to characterize applications as such.

Smart city applications compose a fundamental tier of smart cities: the digital layer of smart cities. They rely on a series of information, communication and programming technologies, most of them have become available during the last fifteen years. From the mid 1990s until now, we can distinguish three consecutive and overlapping waves of technologies that have driven the creation of smart city applications, enabling different forms of *city smartness* or spatial intelligence [12].

*Wave 1:* The World Wide Web initiated in 1990s, but a critical step for reaching a wider public was made with the introduction of the first commercial web browser Netscape in 1994. By 1996 the commercial web was a reality and companies and organizations start having a web presence. The era of digital cities was initiated. The first digital cities were mainly static web pages providing information about the urban area through the combination of texts, data, maps, events, and information services about commerce, recreation and city accommodation. Such digital city applications were described as *mirror-city metaphors*, as their logic was to offer "a comprehensive, web-based representation, or reproduction, of several aspects or functions of a specific real city, open to non-experts" [3]. These applications were developed upon a three-tier architecture composed of a technology for information integration, a technology for public participation with 2D and 3D graphic interfaces, and a technology supported by agents for interaction with citizens [7]. The spatial intelligence of cities related to this technology stack was based on advantages of representation and visualization. Complex urban environments were described and understood better by virtual representations and city metaphors.

*Wave 2:* An increase in communication bandwidth, wider coverage with broadband connections, and the development of Content Management Systems marked a radical change in the web landscape and the digital cities as well. The ideas behind the rise of the Web 2.0 were about sharing, both software and content [8]; the Web 2.0 concept introduced a collaborative and sharing perspective and in many respects it might be considered more as a social innovation than a technological movement. The web became medium on which users interact and collaborate, exchange information, start joint efforts, create virtual communities. The transition to the participatory web appeared with the proliferation of wikis, blogs, social networking sites, media sharing, hosting of web applications, mash-ups and other collaborative web applications, and Enterprise 2.0 applications. The critical change was at the user side, as users became both creators and consumers of content and applications. Web-based collaboration platforms separated programming language and content, and simplified the participation of users. These users could contribute with content without being involved in software code and programming. Web 2.0 cities followed these trends, and new applications for many domains populated the landscape of digital cities. These types of applications correspond better to the fundamental concept of the city as social space of agglomeration and collaboration. This time social interaction and collaboration was taking place on a digital than physical space. Key concepts for the *digital agglomeration* were those of outsourcing and crowdsourcing, opening and transferring tasks and activities to suppliers and the crowd. The spatial intelligence of cities emerging from the web 2.0 technologies was built on collective intelligence and social capital [5]. These are fundamental drivers of innovation and problem-solving capability, outlining the intelligence of cities as a collective rather than an individual achievement. They also paved the way towards Living Labs and other forms of people-driven innovation by introducing the principles of openness, realism, and empowerment of users in the development of new solutions [1].

*Wave 3:* By 2009 the turn to embedded systems and wireless networks marked a new set of technologies for creating the digital space of cities. In [6] this turn towards *Smarter cities* is expressed through the concepts of instrumentation, interconnection and intelligence. Instrumentation means that the working of a city is made measurable by sensors, smart devices and meters; interconnection means that all parts of a city communicate with wired and wireless networks; and intelligence refers to predictive software and modelling for more informed decisions. Within this technology stack intelligence moves out of applications and enters into the domain of data: the meaning of data becomes part of data, data are provided just-in-time, and real-time data enable real-time response. Data and technologies, however, do not lead automatically to new solutions and new services for citizens. The open data urban system demands open innovation models and people-driven innovation models to turn capabilities offered by data and technologies to services and solutions. The Living Labs and other participatory innovation models retain their value to bridge the gap between the technology push of Future Internet testbeds and the application pull of smart cities [10].

## Research Challenges

In this landscape, different traditionally separated streams of scientific research are coming together. New research challenges emerge in and across areas such as urban development and spatial planning, network infrastructure, technology platforms, services and applications, user behaviour, service engineering, innovation theory and urban economics. Also new methodological approaches to research and innovation emerge, such as design science, action research, living labs methodologies, testbed methods and tools, which need a more solid and empirically based foundation in theory as well as in practice. This special issue aims to advance our understanding of the research challenges at the cross point of the different areas mentioned. Such understanding will help academics, governments and practitioners to explore new directions and generate knowledge and solutions towards smarter cities. We specifically have encouraged papers related to user-centred approaches for innovation focusing on smart applications aiming for a transformation towards smarter cities. The resulting collection of six papers addresses a wide range of aspects of smart applications for smart cities.

Schuurman, Baccarne and de Marez investigate crowdsourcing as a process for generating and selecting ideas for innovation in urban environments. They address the strengths and weaknesses of crowdsourcing for idea generation and idea selection in the context of smart city innovation. The principles of crowdsourcing are explained and the different manifestations are demonstrated. By means of a case study, the generation of ideas for innovative uses of ICT for city innovation by citizens through an online platform is studied, as well as the selection process. For this selection, a crowdsourcing solution is compared to a selection made by external experts. The comparison of both indicates that using the crowd as gatekeeper and selector of innovative ideas yields a long list with high user benefits. However, the generation of ideas in itself appeared not to deliver extremely innovative ideas. The authors conclude that crowdsourcing thus appears to be a useful and effective tool in the context of smart city innovation, but should be thoughtfully used and combined with other user involvement approaches and within broader frameworks such as Living Labs.

The paper of Sauer focuses on how smart cities are enabling entrepreneurial to engage in innovation. The starting point is the role of living labs aiming to engage in user-centred design practices where users are included in their daily life environment as innovative agents. Starting from the consideration that empirical insights in end user engagement in Living Lab practices are currently lacking, this article analyzes the involvement of a group of entrepreneurs in a Living Lab smart city pilot, aiming to analyze how and to what extent the Living Lab enabled the involved entrepreneurs to engage in bottom up innovation. The article finds that user innovativeness was limited by the pre-configuration of the entrepreneur as lay tester rather than as an active user-innovator. Furthermore, it is suggested that the inherent tension in Living Lab practices between configuring users and actual user practices hampers user innovativeness in general. A conclusion is that opening up Living Lab practices to daily life dynamics stimulates the transition from tester to innovator in a daily life setting and subsequently makes entrepreneurs more readily *smart*.

Calderoni, Maio and Palmieri study the design, implementation and deployment of location-aware mobile services for a smart city. They design, implement and deploy a smart application that retrieves and conveys to the user relevant information on the user's surroundings. This case study application discusses the challenges involved in creating a location-aware mobile service based on live information coming from the city IT infrastructure. The service that is currently being deployed in the Italian city of Cesena has been designed with the goal of being a general model for future applications. In particular, it is discussed the location-aware and mobile development, cloud and cluster based geographical data storage, and spatial data computation. For each of these topics implementation and deployment solutions are presented based on currently available technology.

Videira Lopes and Lundström present a case study on the use of virtual city in planning for urban development. The authors observe that gearing cities towards a path of sustainability is a challenging task. Change is usually met in reality with enormous resistance from the economic and political models that underlie cities. Powerful tools for promoting change are those related to conceptualization and visualization. When considering urban plans that aren't just incremental improvements over what already exists, city officials, urban planners and the general public must be able to visualize not just the merits of those plans in isolation, but how they interact with all the infrastructure that

already exists. This paper describes one such urban plan that has been under consideration in the city of Uppsala, Sweden, for the past 5 years: a solar-powered Personal Rapid Transit system connecting the main train station to the hospital and the university. The process of discussing this system included the development of a virtual reality simulation of parts of the city. The paper reports on the process and role of this virtual reality simulation.

The paper of Winkler, Ziekow and Weinberg explores the benefits of participatory urban sensing, and uses simulation approaches combined with case validation. Involving citizens in public affairs through the use of participatory sensing applications is an emerging theme in mobile government. The authors take an action design research perspective to provide insight into the often overlooked potential of citizen-centric, external M-Government services. They consider the scenario of a sensing application for reporting urban infrastructure issues to the municipality and present a System Dynamics model to estimate the diffusion, use, and municipal impacts of such service. The model is applied to the case of a large German city, a dedicated survey, and further data sources. The simulation results indicate that, compared to internal information acquisition procedures, the use of urban sensing can improve availability of environmental information at a comparable level of cost. Furthermore, we discuss a number of aspects and learnings related to an urban sensing implementation and provide an empirical estimation of the diffusion model. The results presented provide an impetus for researchers and government practitioners to reconsider the benefits of urban sensing applications in E-Government endeavours.

Finally, the paper of Walravens proposes a new business model framework that allows the design and analysis of value networks for mobile services in a public context. It starts from a validated business model framework that relies on a set of design parameters to evaluate business models. This is expanded by eight parameters to include important aspects that come into play when a public entity (i.e. a city government) becomes involved in the value network. This framework is applied to the case of the 311 service offered by the City of New York. Given the quickly changing power relations in the mobile telecommunications industry, this framework offers both an academic and practical tool, enabling the comparison and analysis of mobile city service business models.

Overall, this collection of papers in this Special Issue covers a range of different topics and methodologies. Interestingly much attention is paid to empirical evidence for measuring and evaluating the impact of applications and cities, as well as the introduction of methodology frameworks from social sciences. Integrating such frameworks with technical approaches to smart applications development in living lab environments constitutes a promising and rich research area for the next years.

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