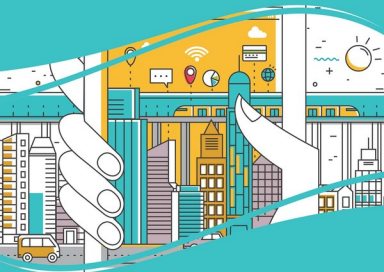


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Enriching Urban Spaces with Ambient Computing, the Internet of Things, and Smart City Design



Shin'ichi Konomi and George Roussos



Enriching Urban Spaces with Ambient Computing, the Internet of Things, and Smart City Design

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A volume in the Advances in Human and Social
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Mary Beth Rosson, The Pennsylvania State University, USA

Kyungsik Han, Pacific Northwest National Laboratory, USA

The Internet of Things integrates entities of the physical world by making them addressable through the Internet, and making the Internet accessible through physical objects. We draw on our own previous design research in community informatics to explore a critical elaboration of the Internet of Things: The Internet of Places (IoP). IoP seeks to support awareness, engagement, and interaction pertaining to individual and collective human experiences, meaning making, activity, intentions, and values by computationally leveraging and integrating a wide range of human data with places to which those data refer. We describe design scenarios, prototypes, and user research at the scale of local community. We identify a critical alternative for humankind of hyperlocal community, enabling greater citizen awareness, engagement, participation, and power. We suggest that the Internet of Places at community-scale is the next generation infrastructure for community networks in the 40-year tradition of the Berkeley Community Memory.

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Marketa Dolejsova, National University of Singapore, Singapore

Denisa Kera, National University of Singapore, Singapore

The Fermentation GutHub is a local community of fermentation enthusiasts in Singapore formed around ‘smart’ human-microbial interactions. The project is a critique of the common IoT utopia claiming efficient and transparent interactions between citizens and various stakeholders using smart sensors and monitoring devices in the cities of the future. Instead of relying on technology produced and supported by corporate actors or large government plans, the GutHub scenario uses existing fermentation groups and DIY tools as a model for designing resilient and symbiotic urban communities. Against the utopia of

evidence-based decision making driven by policy and corporate actors, it emphasizes the importance of collective experience with risk and opportunities negotiated on a grassroots level. The project supports citizens' exchanges of various cultures, fermentation practices, and sometimes dangerous but also beneficial experiments with our guts as an interface, and proposes a model for messier IoT scenarios of future cities.

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Assembly, Space, and Things: Urban Food Genome, Urban Interaction, and Bike Share..... 47

Philip Speranza, University of Oregon, USA

Jason O. Germany, University of Washington, USA

Each day as one notices more people walking along sidewalks, head down peering into smart phones, the fear is that social interaction in public space is dead. However, the integration of human and non-human processes may connect our communities now in more ways than ever before. New urban design theory suggests that “the city” may not be understood as a whole, rather as an assembly of dynamic urban processes. At many bike share systems around the world only static maps with limited interaction experience. Urban interaction design and the Internet of Things, is changing this experience. The interdisciplinary methodology describes a symbiosis of people, space and things. The significance is the integrated urban interaction design process of: urban design theory using classification of urban experience; geospatial analysis at the street-scale of point addresses, and fabrication of a test-bed kiosk to test ambient sensors and user interaction. Connectivity experienced in the virtual space of social media may now enter back into the physical realm of public space.

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In this chapter, the authors focus on temporal patterns of urban taxi trips and explore determinant factors in conjunction with geodatabase at aggregate level. Zero-Inflated Negative Binomial model is proposed in light of count data nature and excessive number of O-D pairs with zero trip. Three typical time slots on weekdays, as well as weekends, are introduced as case study to check temporal variations of intra-city movement. The results indicate that trip distance, land use, socioeconomics, and built environment are significant variables that affect the number of taxi trips between two locations. In particular, longer travel and worse economy conditions, such as low employment and average annual income and more population under poverty, may prevent more movements, which have more impacts during peak hours. A better transit system may reduce the taxi trips, except for areas with more subway stations. Developed area for instance more commercial or residential area is more likely to attract more visits by taxis, as well as dense public facilities but with more temporal variations.

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Marco Negretti, Politecnico di Milano, Italy

Secil Ugur Yavuz, Politecnico di Milano, Italy

The increasing use of technologies like smart phones and mobile apps enables people to be actively involved in collecting data that can be the base of useful services to the whole citizenship. In the realm of volunteer data collection, this chapter addresses the problem of mobility and accessibility limitations for vulnerable citizens in today's cities. The MEP (Maps for Easy Paths) project proposes a set of tools and mobile apps for the enrichment of geographical maps with information about accessibility of urban pedestrian pathways, targeted at people with mobility problems. Different issues are considered and discussed in this chapter, including: the problem of collecting data of a user's route and of reconstructing it with novel sensor fusion techniques; the problem of correcting the positions obtained from low-cost GNSS receivers of mobile devices; the need of usable and accessible applications for the fruition of the collected data suitable for the target users.

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Jarogniew Rykowski, Poznan University of Economics, Poland

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In this Chapter a new way of payments for Internet of Things services is proposed, based on a stream of anonymous pico-payments realized by means of pico-coins. System architecture and information flow are presented, showing fully automated way of contextual payments which protect customers' privacy. With the proposed stream of pico-payments, two basic problems of efficient and widely acceptable payment method for the Internet of Things are solved: privacy protection, and toleration of frequent unexpected disconnections.

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Co-Producing Tools for Participation and Action in Urban Environments 128

Corelia E. Baibarac, University of Sheffield, UK

The chapter addresses the potential of co-production in relation to enhancing the participation of a city's inhabitants in its design, management and use. It does this by discussing a co-design process, which explored how participation might be extended to the design of digital platforms that could allow city inhabitants to be involved in the identification of needs, goals and actions for their everyday environments. The chapter outlines three spatial-technological experiments involved in the co-design process and the

resulting web 2.0 platform prototype, which illustrates how collaborative technologies might stimulate collective actions. Acknowledging the importance of creating opportunities and spaces for reflection within technology-enabled participatory processes, the notion of co-production is extended to the iterative and collaborative production of knowledge and actions for the city. In this conceptualization, inhabitants' role shifts from that of 'users' or 'consumers' to active (and reflective) 'co-producers' of a more resilient city together with the decision-makers.

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Dimitrios Ringas, Ionian University, Greece

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The work presented in this chapter delineates the longitudinal experience of deploying an urban computing system that enables citizens to share and interact with digital content about the urban environment and experiences of people with it. It is part of an emerging and novel aspect of urban computing that expands research beyond simple optimisations of city functions towards a social and cultural approach that seeks to orchestrate complex socio-technical ensembles. Offering Collective City Memory as a service to citizens and enabling them to interact with it via diverse novel interfaces has uncovered the implications for city life that the introduction of urban computing brings such as the redefinition of spatial and temporal proximity and the effects on the perception of city space, fostering of social interactions, contribution to shared resources and participation in collective efforts.

Chapter 9

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Burak Pak, University of Leuven, Belgium

This chapter aims to envision design approaches for creating ubiquitous interactive spaces which can empower the users to shape and reshape their living environments. It starts with the discussion of the affordances of networked sentient technologies to facilitate cycles of reflexivity through a comparative case study. Based on this analysis, the author distils key principles for future practices including: incomplete, dynamic architectural program, continuous representation of the user needs, incorporation of user variety and differences, embracing open-endedness, self-organization and spontaneity in use. Following these principles, the author reveals a conceptual design for a sentient space in Ghent as a means to demonstrate action possibilities latent in ubiquitous spaces. In conclusion, the author shares lessons learned and elaborates on future directions.

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Social Media Geographic Information: The Community Perspective in Planning Knowledge 184

Michele Campagna, Università di Cagliari, Italy

Roberta Floris, Università di Cagliari, Italy

Pierangelo Massa, Università di Cagliari, Italy

Sara Mura, Università di Cagliari, Italy

Since last decade, advances in the Information and Communication Technology (ICT) are increasingly enabling the voluntary sharing of user generated contents. Among different emerging digital resources, georeferenced multimedia data publicly shared through social media platforms, or Social Media Geographic Information is starting to stand out in quantity and value as data resource. In spatial planning, where the

majority of information required to support analysis, design, and decision-making is inherently spatial in nature, SMGI may foster notable innovations in methodologies and practices, allowing the integration of both experiential and professional knowledge on places, events and ambient. However, this hypothesis should be carefully tested. With the above premises, this chapter more specifically concerns the concept of Social Media Geographic Information, arguing that it may represent an unprecedented resource for expressing pluralism in such domains as spatial planning where it may convey the community collective preferences contributing to enrich knowledge for decision-making.

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Urbanizing the Ambient: Why People Matter So Much in Smart Cities.....	209
<i>H. Patricia McKenna, AmbientEase, Canada</i>	

The purpose of this chapter is to develop and explore the ambient urbanizing concept as a way to shed light on what happens at the urban level when people become more aware and attuned to smartness and ambience in everyday city spaces. The research design for this work includes a case study approach and multiple methods of quantitative and qualitative data collection and analysis. In parallel with this study, anecdotal evidence gathered from individuals across the city through informal individual and group discussions enabled further analysis, comparison, and triangulation of data. This chapter makes a contribution to the research literature across multiple domains; sheds light on the emerging relationships of awareness in the people – technologies – cities dynamic, highlighting the critical role of people, in their everyday urban activities, interactions, and experiences; and offers a proposed ambient urbanizing framework for enriching spaces, things, and designs in smart cities.

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<i>Mizuki Sakamoto, Waseda University, Japan</i>	
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We now typically live in modern cities, where ubiquitous computing technologies such as advanced sensing enhance various aspects of our everyday lives. For example, smart phones offer necessary information to make our everyday lives convenient anytime, anywhere in the city; energy management and traffic management have become smarter, making our everyday lives more convenient and efficient. However, from a citizen perspective, the well-being of citizens needs to be more essential than merely achieving efficient and convenient smart city infrastructures. We think that this issue is particularly crucial for establishing the next generation of smart city design. In this chapter, we propose a social infrastructure named flourished crowdsourcing to make our society flourish, so diverse citizens will live comfortably and happily. To achieve a flourishing society, one of the most essential issues is making diverse citizens activists who will participate in socially collective activities. Traditional approaches such as gamification typically make it possible to guide the social activities of the average number of citizens, but it is not easy to maintain activities for diverse citizens. By incorporating fictionality into the real space, our approach is to increase the social awareness of citizens to achieve a flourishing society within each citizen's community so that they see the necessity of their contribution. To design and analyze fictionality, we also propose a gameful digital rhetoric as design abstractions. The design abstractions are extremely different from traditional approaches; designers can explicitly focus on the enhancement of the meaning in the real space from multiple perspectives; thus designers can change the meaning incrementally according to rapidly changing social situations or citizens' diverse preferences.

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Geisa Bugs, Feevale University, Brazil

Marketta Kyttä, Aalto University, Finland

This chapter addresses PPGIS (Public Participation Geographic Information Systems), a participatory method through which the public can produce maps and spatial data that represent their perceptions of the urban space in question. Specifically, it analyzes the data collected from an experiment in Jaguarão, Brazil. The data represents the perceptions of a small group of inhabitants about the problems and potential of the city's urban area. The procedures include an exploratory analysis and data visualization in the form of maps that allow describing a variable's distribution and identifying patterns. Moreover, for some issues, the authors cross the perception collected data with infrastructure data, socioeconomic data, and cadastral data to study possible associations among these different types of information layers. The results show that public perception, collected through PPGIS, forms an additional information layer that could be analyzed together with other information layers commonly used in urban planning, and thus to be taken into account for designing better cities.

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Preface

The idea of spreading computing ubiquitously and integrating it in the context of “the real world” has driven the developments of innovative systems during the last 25 years. Today, people interact with computing systems in various kinds of spaces including rooms, houses, buildings, streets, neighborhoods, and cities, using smartphones, public displays, internet of things, and so on.

We are now going beyond the last decade’s conception of smart cities and urban computation and towards a deeper level of symbiosis among smart citizens, internet of things, and ambient spaces. Earlier efforts focused on convenience and efficiency by for example inferring simple patterns and controlling resources. As computers become less and less visible physically and mentally as Mark Weiser predicted (Weiser, 1991), computing pervades deeper into the complex web of people, spaces, objects and practices opening up a new frontier for creating livable and enjoyable environments for citizens.

This book brings together various ideas from different schools of thought to explore changing perspectives of computing and urban spaces in this context. What can influence such perspectives are not only recent technological developments such as crowd computing, internet of things, and data-centric computing but the confluence of ideas and critiques from all kinds of disciplines that have a stake in making ubiquitous spaces livable and enjoyable for citizens. The book discusses fundamental components of urban environments such as people, things, and spaces, which together can play important roles to cope with the critical challenges for the cities in the 21st century, including resilience and sustainability.

Brief discussions of each topic follows:

- **People (Smart Citizens):** Personal mobile devices that have powerful computing, sensing, and communication capabilities have proliferated in urban spaces in the last 10 years (Pew Research Center, 2014). They have been used to deliver location-relevant information to consumers and monitor their whereabouts and activities (Reades, Calabrese, Sevtsuk & Ratti, 2007; Eagle & Pentland, 2006). Increasingly, other novel ideas to exploit such devices in public spaces are in view of the smartness of citizens and their social networks and capital (Putnam, 2001). For example, smartphones can empower citizens by enabling novel forms of collaboration and participation to cope with wicked problems as explored in recent developments in computational environments supporting civic engagement, mobile crowdsourcing, sharing economy, empowerment, learning and democracy (Foth, Forlano, Satchell & Gibbs, 2011; Foth, Brynskov & Ojala, 2015).
- **Things (Internet of Things):** Although the idea to embed computation in things (e.g., RFID-embedded physical objects) was proposed previously, oftentimes they have been confined in non-public spaces such as distribution centers, warehouses, and retail stores until recently. Now that networked RFID (Roussos, 2008) and other embedded networked technologies are gaining richer

computation, sensing, communication, and actuation capabilities and spreading into everyday things around citizens, their design and deployment can have direct impacts on citizens' everyday lives as they monitor and control things automatically at scale to save energy and live safer and healthier and responds to citizens' tangible and embodied interactions to assist and influence their activities. Although this may conjure the image of "high-tech utopia" (Arbes & Bethea, 2014), open hardware, open data and DIY movements (e.g., Gray Area, 2012) introduce further opportunities and challenges as motivated citizens can make their own Internet of things, places, people and microbes, and share their data on open repositories relatively easily.

- **Spaces (Ambient Spaces):** Many ubiquitous computing projects have instrumented rooms, houses (Kid et al., 1998) and buildings (Streitz, Geißler & Holmer, 1998) with sensing, computing, communication and display devices. By surrounding users with computing technologies, systems could infer users' context and provide them non-intrusive services such as ambient presentation of contextually relevant information. Some of the current ubiquitous technologies such as public displays seem to blend more nicely in public context than experimental devices in the early days of ubiquitous computing. By closely examining relevant cases in view of different conceptual and critical perspectives, we may begin to understand how one can design and blend technologies successfully in complex contexts such as public spaces. This may have to do with advanced data-centric computational intelligence as well as cognitive, psychological, social, political, economic, historical, geographical and cultural factors that are embedded in unique local contexts. Recent developments in ambient spaces allow for more informed discussions on the right integrations of ubiquitous computing in architectural and urban spaces (McCullough, 2013).
- **Resilience & Sustainability:** The world has experienced many tragic events in the last 15 years and is facing important challenges in the areas of energy, food, economy, public safety and health as well as disaster response and preparedness. With this background, the world-wide efforts to make cities resilient and sustainable have provided important contexts for ubiquitous computing in urban spaces. Besides the provision of smart and reliable infrastructures that can withstand disasters, case studies and reports show that social media, mobile crowdsourcing, and volunteered geographic information have important roles to play in this context (Olteanu, Vieweg & Castillo, 2015). Volunteers are exploiting DIY Internet of Things to cope with disasters (Safecast, n. d.) as well. Moreover, ubiquitous urban spaces can help strengthen cohesion and mutual support in local communities thereby increasing their resilience and sustainability.

As things develop in these areas, discussions emerged around various relevant concepts including Urban Computing and Informatics (Shklovski & Chang, 2006; Williams & Dourish, 2006; Kindberg, Chalmers & Paulos, 2007; Foth, 2009), integration of built environments and information spaces (McCullough, 2004; McCullough, 2013; Shepard, 2011), Smart Cities (Townsend, 2013; Greenfield, 2013), urban interaction (de Waal, 2014; Brynskov, 2014; Silva & Frith, 2012), urban social interaction (Willis, Roussos, Chorianopoulos & Struppek, 2010; Paulos & Goodman, 2004), and Community Informatics (Carroll, 2014).

Again, the book aims at establishing broader perspectives of computing and urban spaces beyond the last decade's narrow utilitarian conceptions. This subject area is at the intersection of multiple disciplines including computer science (e.g., ubiquitous computing and human-computer interaction), architecture, urban planning, geography, economics, politics, psychology, sociology, urban studies, communication studies, etc. The accelerating developments in this area make it an urgent requirement to bring together

the ideas and developments in an increasing number of relevant projects and disciplines. Connecting the developments in various relevant disciplines can form an intellectual backbone that generates more informed outlooks of the futures and increased interdisciplinary collaboration to accelerate the development in this complex problem space, towards the goals of societal importance such as making resilient and sustainable cities.

ORGANIZATION OF THE BOOK

The book includes 13 chapters that are organized into two sections: and “Internet of Things, Places, People and Microbes” and “Enriching Urban Spaces.” A brief description of each chapter follows:

Section 1: Internet of Things, Places, People, and Microbes

In Chapter 1, John M. Carroll, Patrick C. Shih, Jess Kropczynski, Guoray Cai, Mary Beth Rosson, and Kyungsik Han discuss the Internet of Places (IoP) by drawing on design research in community informatics. IoP seeks to support awareness, engagement, and interaction related to individual and collective human experiences, meaning making, activity, intentions, and values by computationally leveraging and integrating a wide range of human data with places to which those data refer. The chapter describes design scenarios, prototypes, and user research, and suggests that the Internet of Places at community-scale is the next generation-infrastructure for community networks in the 40-year tradition of the Berkeley Community Memory.

In Chapter 2, Markéta Dolejšová and Denisa Kera present the Fermentation GutHub project, which is a local community of fermentation enthusiasts in Singapore formed around ‘smart’ human-microbial interactions. Against the utopia of evidence-based decision making driven by policy and corporate actors, it emphasizes the importance of collective experience with risk and opportunities negotiated on a grassroots level. The project supports citizens’ exchanges of various cultures, fermentation practices, and sometimes dangerous but also beneficial experiments with our guts as an interface, and proposes a model for messier IoT scenarios of future cities.

In Chapter 3, Philip Speranza and Jason O. Germany describe the work that focuses on “the city” as an assembly of dynamic urban processes involving humans and non-humans. The work examines a comprehensive taxonomy of urban experience called the Urban Genome, which can be leveraged in combination with spatial data to better connect a community. To make the proposed framework actionable and accessible to the street-level users, the authors utilize a bike share kiosk prototype called Urban Interaction Portal. They also discuss the potential of the proposed platform to collect and display data using various sensors and GIS platforms.

In Chapter 4, Wenbo Zhang, Xinwu Qian, and Satish V. Ukkusuri look into the flows of people in a city by surveying temporal patterns of urban taxi trips and investigating determinant factors in conjunction with geo-database at aggregate level. Three typical time slots on weekdays, as well as weekends, were modeled to validate temporal variations of intra-city movement. The results showed that trip distance, land use, socioeconomics, and built environment are significant variables that affect the number of taxi trips between two locations. The chapter discusses further details that can inform the planning and design of urban environments.

In Chapter 5, Ludovico Biagi, Sara Comai, Raffaella Mangiarotti, Matteo Matteucci, Marco Negretti, and Secil Ugur Yavuz present the MEP (Maps for Easy Paths) project that proposes a set of tools and mobile apps for the enrichment of geographical maps with information about accessibility of urban pedestrian pathways, which can support people with mobility impairments. The approach they propose collects data from mobile devices in an implicit manner and reconstructs the users' travel paths based on sensor fusion and GNSS correlation techniques. This is complemented by the user-centered interface design in this multi-disciplinary project involving different competences, ranging from computer science to geomatics and design.

In Chapter 6, Jarogniew Rykowski and Wojciech Cellary propose a payment method for the services that exploit the Internet of Things. The proposed method is based on a stream of anonymous pico-payments realized by means of pico-coins. The chapter presents the system architecture and information flow, showing a fully-automated, privacy-preserving contextual payment method. The stream of pico-payments is proposed as solutions to the problems of privacy violation and frequent unexpected disconnections, which are critical to enable efficient and widely acceptable payment method for the Internet of Things.

Section 2: Enriching Urban Spaces

In Chapter 7, Corelia E. Baibarac discusses the potential of co-production in relation to enhancing the participation of a city's inhabitants in its design, management and use. The chapter describes experiments based on a co-design process as well as a prototype collaborative platform, which leads to the discussions of an extended notion of co-production considering the iterative and collaborative production of knowledge and actions for the city. The discussions highlight the shift of citizens' roles from the passive ones as 'consumers' to the active and reflective ones as 'co-producers' of a more resilient city together with the decision-makers.

In Chapter 8, Dimitrios Ringas and Eleni Christopoulou present their longitudinal experience deploying an urban computing system that allows citizens to share and interact with digital content about urban environments and experiences. The chapter highlights the possibility to build Collective City Memory, and discusses the implications of their experience from various perspectives including spatial and temporal proximity, perception of urban spaces, social interactions and participation.

In Chapter 9, Burak Pak discusses design approaches for creating ubiquitous interactive spaces that can empower the users to shape and reshape their living environments. The chapter reviews various design cases that incorporate ubiquitous computing and sentient technologies, and derives alternative design strategies based on two modes of empowerment, which supports ordinary people to make and remake their urban spaces. This leads to the proposal of key principles for future practices, including: incomplete, dynamic architectural program, continuous representation of the user needs, incorporation of user variety and differences, embracing open-endedness, self-organization and spontaneity in use. Following these principles, the author presents the conceptual design of a sentient space in Ghent as a means to demonstrate action possibilities latent in ubiquitous spaces.

In Chapter 10, Michele Campagna, Roberta Floris, Pierangelo Massa, and Sara Mura focus on ever-increasing geo-referenced multimedia data that are publicly shared through social media platforms, or Social Media Geographic Information (SMGI). Based on the case studies related to tourism planning and urban planning, the authors argue that SMGI may represent an unprecedented resource for expressing pluralism in such domains as spatial planning where it may convey collective preferences of the community and contribute to enrich the knowledge that can be used for better decision-making.

Preface

In Chapter 11, H. Patricia McKenna develops and explores the ambient urbanizing concept as a way to shed light on what happens at the urban level when people become more aware and attuned to smartness and ambience in everyday city spaces. Based on a case study and anecdotal evidences, this chapter makes a contribution to the research literature across multiple domains; sheds light on the emerging relationships of awareness in the people – technologies – cities dynamic, highlighting the critical role of people, in their everyday urban activities, interactions, and experiences; and offers a proposed ambient urbanizing framework for enriching spaces, things, and designs in smart cities.

In Chapter 12, Mizuki Sakamoto and Tatsuo Nakajima discuss a flourished crowdsourcing infrastructure that incorporates fictionality to guide collective human behaviors in cities towards comfortable and happy lives. The chapter elaborates on the design and analysis of fictionality in flourished crowdsourcing, and proposes relevant design abstractions based on the notion of design fiction. A prototype of a flourished crowdsourcing environment has been developed and tested, which leads to the discussions of broader design implications.

In Chapter 13, Geisa Bugs and Marketta Kyttä present the work on Public Participation Geographic Information Systems (PPGIS), a participatory method through which the public can produce maps and spatial data that represent their perceptions of the urban space in question. They look into the data collected from an experiment in Jaguarão, Brazil, which represent the perceptions of a small group of inhabitants about the urban area. The results show that PPGIS can create an additional information layer that can be considered in the processes to plan and design better cities.

We hope the book is useful for everyone who is interested in this topic. In particular, researchers and practitioners who design, develop, deploy, test, and/or exploit computing in urban settings could use the book to inform their professional practices. Researchers and practitioners in computer science, architecture, urban planning, geoinformatics, geography, regional studies, and communication studies who do not directly work on computing in urban settings but are interested in the topic could use the book to broaden the scope of their ideas and activities. Educators and students in computer science, architecture, urban planning, geoinformatics, geography, regional studies, and communication studies could use it as a reference book.

Finally, we would like to acknowledge the help of all the people involved in this project and, more specifically, to the authors, the Editorial Advisory Board members and the reviewers. Without their support, this book would not have become a reality.

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Section 1

Internet of Things, Places, People and Microbes

Chapter 1

The Internet of Places at Community-Scale: Design Scenarios for Hyperlocal Neighborhood

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ABSTRACT

The Internet of Things integrates entities of the physical world by making them addressable through the Internet, and making the Internet accessible through physical objects. We draw on our own previous design research in community informatics to explore a critical elaboration of the Internet of Things: The Internet of Places (IoP). IoP seeks to support awareness, engagement, and interaction pertaining to individual and collective human experiences, meaning making, activity, intentions, and values by computationally leveraging and integrating a wide range of human data with places to which those data refer. We describe design scenarios, prototypes, and user research at the scale of local community. We identify a critical alternative for humankind of hyperlocal community, enabling greater citizen awareness, engagement, participation, and power. We suggest that the Internet of Places at community-scale is the next generation infrastructure for community networks in the 40-year tradition of the Berkeley Community Memory.

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INTRODUCTION

In the 1960s, the futurist Marshall McLuhan (1962) envisioned a “global village”. A version of this future is here. The Internet brings all people closer to one another. Much contemporary innovation is directed to unprecedented cloud resources and services, and the Internet mediated, massive-scale educational, recreational, social, and professional interactions they afford. We are just beginning to fathom this trajectory toward a global village of humankind.

In this paper we explore the thesis that the global village requires local communities to provide social foundation for more complex and distributed societal institutions and capacities (Carroll, Shih, & Kropczynski, 2015; Perera, Zaslavsky, Christen & Georgakopoulos, 2014). In particular, we draw on the thread of research inaugurated by the Berkeley Community Memory (BCM) (Rossman, 1975). In the 1970s, before there ever was an Internet, activists in Berkeley created a mainframe system, implemented through a 110-baud link to teletype terminals. BCM included discussion forums directed at local and national issues, and online postings of community information about car pools, apartment vacancies, chess games, restaurant reviews, and musical instruments to buy or sell. People posted their poetry and essays. One of the terminals was located beneath the bulletin board in a local record store; users started calling it an “electronic bulletin board”. Activists created an online memorial to Alameda County’s Vietnam War casualties.

Rossman’s (1975) paper on BCM reported action research on universal accessibility, social leveling, and strong democracy principles that seem current 40 years onward, and that guided a long series of community network projects (Carroll, 2012; Schuler, 1996), and firmly established the design principle that the purpose of community networks is to inform and engage the community, and to enable community action. We take this work as a model inspiration for how enabling local community can facilitate the development of national and global community, as a seed crystal can enable the development of a robust, larger-scale crystal lattice.

In this paper, we describe design research on community services and information infrastructures inspired by BCM, but leveraging contemporary technological possibilities of the Internet of Things (IoT), that is, the integration of entities of the physical world by making them addressable through the Internet, and making the Internet accessible through physical objects. In our project, places in the local community are indices into a networking infrastructure for individual and community information and interaction.

It is quite useful to associate physical data with locations at which these data are obtained (Goodchild Guo, Annoni et al., 2012; Schafer, Ganoë, Xiao, Coch & Carroll, 2005). Our interests, however, transcend spatially indexing physical data; we are most concerned with the challenge of enhancing awareness, engagement, and interaction pertaining to individual and collective human experiences, meaning making, activity, intentions, and values by computationally leveraging and integrating a wide range of human data with places to which those data refer. We refer to this specialization of IoT as the Internet of Places.

Emphasizing the meanings of local places to the people that inhabit them can strengthen local community identity. The history, heritage, and special purposes of community places can be invisible even to the people who pass by them every day. Allowing community places to serve as indices into digital interactions and information makes them more visible, but also provides new ways to become aware and participate in the community. It makes community information and interaction hyperlocal (Farhi, 1991): Created by local people, about local places and events, and directed to local people to be accessed locally. This powerfully updates the electronic bulletin boards of BCM: In the Internet of Places (IoP), we do not merely refer to and discuss local places and place-based events, we interact with them

directly, their geo-spatial coordinates are part of the underlying computation. In this sense, we argue, places can speak for themselves, host community history and heritage, facilitate community activities, mediate citizen interaction, and guide local political discussion and decision-making.

In the early 1970s, the developers of the BCM were pursuing a vision of greater equity in citizen access and participation by putting community information and activities online, and putting terminals in public spaces. New information infrastructures raise many new possibilities. According to a recent study from by Pew Internet & American Life, 56% of American adults now own a smartphone; smartphone adoptions have increased rapidly since 2011 in every demographic (Smith, 2013). According to a survey from YellowPages, nine out of 10 people “almost always” have their mobile devices with them, and most permit mobile applications to access their “current location” at least some of the time (Hendrix, 2013). People use smartphones not only as communications devices, but also for personal computing (Karlson, Meyers, Jacobs, Johns, & Kane, 2009). The especially high adoption rate among young adults is an indicator of future societal trends. New information infrastructures raise many new possibilities. Smartphones enable mobile/location sensitive information interactions not before possible (Ganoe, Robinson, Horning, Xie & Carroll, 2010; Geser, 2004; Paulos, Honicky & Hooker, 2009). We are investigating ways that “smart spaces” can enrich the range of possible mobile experiences and interactions, specifically to enhance citizen awareness of and increase participation and engagement in local activities, news, plans, and possible social opportunities.

THE INTERNET OF PLACES

In 1999, Kevin Ashton detailed the vision of the “Internet of Things” (IoT) that focuses on the need “to empower computers with their own meanings of gathering information, ... enable computers to observe, identify and understand the world—without the limitations of human-entered data” (Ashton, 2009). IoT articulates three converging visions: a vision of connected things, a vision of powerful and pervasive Internet connectivity, and a vision of large-scale data analytics (Atzori, Iera & Morabito, 2010).

In the “things”-oriented vision, researchers focus on improving the capabilities of RFIDs, sensors, or tiny and battery-operated embedded devices (Welbourne et al., 2009). These devices are capable of detecting changes in the environment and providing real-time and up-to-date information to inform better decision-making process. The sensors are typically networked in a peer-to-peer fashion or connected to a central server. In some cases, these devices are also capable of sophisticated computations. Smartphones and wearable activity trackers are already showing this trend.

In the Internet-oriented vision, researchers focus on building out the cloud-computing infrastructure (Perera, Zaslavsky, Chriten et al., 2014). Cloud-computing goes beyond the simple network transmission protocols enabled in sensors and embedded devices in that the sensors not only communicate with each other, but they are also constantly-on, and the information stored in the cloud is also accessible anytime and anywhere. Current state-of-the-art cloud-computing infrastructure focuses on improving transmission bandwidth and storage spaces so that a larger amount of information can be transferred and stored more quickly.

In the “semantic”-oriented vision, researchers focus on leveraging big data analytics to integrate semantic information transmitted by embedded devices via cloud-computing infrastructure (Ringas, Christopoulou & Stefanidakis, 2011). Trends and patterns formulate semantic meanings that can be utilized in context-aware applications. For example, depending on the user’s current location and infor-

mational needs, semantically-powered computational systems could make relevant recommendations on how to best locate the resources depending on the user's context.

The Internet of Things integrates objects of the physical world by making them addressable through the Internet, and making the Internet accessible through physical objects. This is an inspiring and challenging vision for information infrastructures.

Our vision for an Internet of Places specializes and extends the Internet of Things. We specialize IoT by focusing on a particular category of thing, integrating places as collective ensembles of physical objects that function as physical settings for community activities. We extend IoT by focusing on places as socially constructed, intentional, and contested. IoP seeks to make experiential, affective, and intentional aspects of places more visible, accessible, interactive, and sharable. IoP should support humans in place-making, help them experience and develop identity through everyday community activities, become more engaged and participate in community activities, and build effective multifaceted local social network.

Key to our analysis is the distinction between “space” and “place” (Harrison & Dourish, 1996): space refers to the structural, geometrical qualities of a physical environment, place includes the dimensions of lived experience, interaction, and use of a space by its inhabitants. Spaces become places through being inhabited, used, appropriated, and transformed in human activity. That is to say, people make places through their activity (Duff, 2010; Lee, Danis, Miller & Jung, 2001). A classic example is Hester's (1993) analysis of the town of Manteo, North Carolina, as a “sacred structure” of specialized activity hubs, places, overlaying a mundane physical space. Communities assign rich meanings to their local places and maintain a sense of place that is conceived of as being a highly multidimensional experience conveyed through environmental, social, and cultural attributes of places, in addition to people's psychological responses to these attributes (Thrift, 2004). Places are fundamental constructs that structure social practices, cultural history, memory, experiences, emotion, and material environment that people live in. The physical environment and the meaning, identity, sense of attachment and belonging are facets of places that are profoundly significant and inseparable (Green, 2010). IoP enables and amplifies the capacity of individuals and communities to interact and engage with each other through place-based infrastructures.

IoP extends visions of the digital Earth (Goodchild et al., 2012). During the past 20 years, the geospatial revolution has amassed a set of interlocking technologies – global positioning systems (GPS), sensor platforms (satellite images), closed circuit television (CCTV) cameras, GPS enabled devices, and radio frequency identification tags (RFID), GIS and spatial data analysis. These technologies have fundamentally changed the relationship between people and the world (Downs, 2014), making vast amounts of real-time digital data about people and places readily available, but for the most part focused on physical aspects of use and state, for example, water quality readings for a local stream posted on an interactive map (Schafer et al., 2005).

The distinction between space and place became an important design concept in the 1990s as collaborative systems increasingly employed spatial presentations and interactions, and it became critical to distinguish lower-level spatial navigation and interaction from the shared conventions, cultural understandings, and practices that socially constitute a virtual place (Harrison & Dourish, 1996).

These two lines of conceptual development converge in community informatics where place becomes one's community or neighborhood (Carroll et al., 2001; Jones, Grandhi, Terveen & Whittaker, 2004), constituted by everyday activities that shape personal identity, social engagement and participation, and multifaceted relationships.

In the balance of this paper, we develop and illustrate the IoP concept by exploring five conjectures:

- IoP should enable appreciation of the nuance of everyday places. The incidental meanings and emotions evoked by those places can be associated with and shared through location.
- IoP should strengthen awareness and engagement in local heritage. Information, discussion, and experiences about the history of places and events can be associated with and shared through location.
- IoP should integrate community activity, making public activity more visible and connected to community resources, and encouraging diverse perspectives on local news and events.
- IoP should provide new ways to participate in community life, mediating interactions among neighbors to enrich discussion and shared activities, including giving and receiving help.
- IoP should support interactions with and participation in local anchor institutions, including municipal government, helping to make people more aware of positions and rationales regarding political issues and initiatives, and of plans for community development.

Everyday Places Are Nuanced

People moving within a community are constantly experiencing the world around them. They see roads closed for repair, buildings being restored or torn down, park gardens being groomed. Some of the experiences are salient, like noticing an approaching vehicle and stepping back onto the curb until it is safe to cross the street. Other experiences are highly nuanced, barely noticed. One person walks by a construction site and wonders what was there before, or what is happening now. Another person walks for blocks without “seeing” anything.

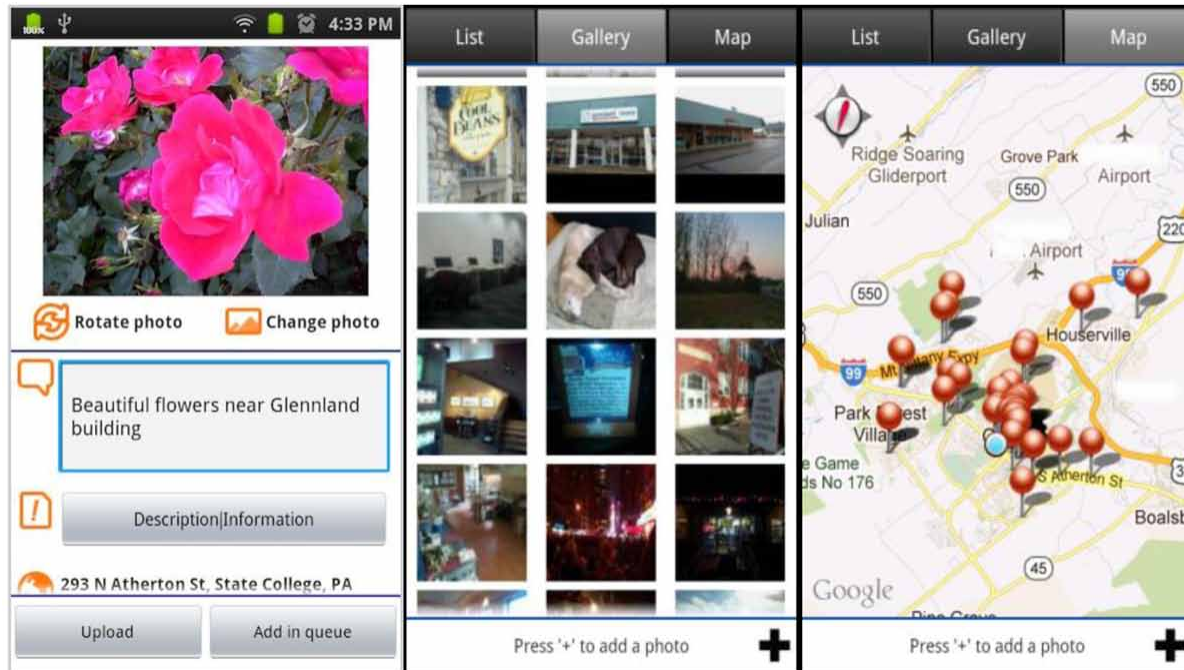
IoP enriches geographical locations by directly associating information, interactions, and services with geographic coordinates, including personal meanings, experiences, and emotions. Thus, a resident might have an emotionally powerful place-based experience when looking at a freshly blooming flower. Acknowledging, codifying and sharing an experience like this is one way for community members to identify with local places and events. Here and Now (Figure 1) makes it easier to share place-based personal moments, and to recognize the nuances of the community places that evoke them.

Here & Now extends the traditional notion of digital storytelling (Klaebe, Foth, Burgess & Bilandzic, 2007) by allowing users to upload an image of an object or activity along with a brief description using a smartphone (Carroll, Hoffman, Han & Rosson, 2015). The Here and Now contribution is geo-tagged with the person’s current location. The posts are viewable on a map, so that mobile users can find and enjoy the contributions made near their current location, or browse Here & Now contributions more broadly using a map. Once a post is selected, viewers can also contribute their own thoughts or reactions.

Here & Now photos and comments are attributed to the individual community members who contributed, reducing the chance that the system will fill up with “junk” content. As a result, the use of Here & Now requires user authentication, which we have simplified by allowing reuse their Facebook credentials. The reuse of Facebook credentials also enables residents to choose to share community activities with their larger Facebook audience.

As Here & Now contributions accrue, the associated community places begin to “speak” for themselves in a hyperlocal fashion. When people pass by, they can interact with not only the physical place, but also its digital doppelganger, bringing to light the recent special features of that place that have been called out by photos, comments, and so on. Through the interactive community map that presents Here

Figure 1. Here & Now: Add photo page (left), a list of photos posted by users (mid), and a map view of photos (right)



& Now records that are nearby, people can learn about other places that have something to say. Currently we are studying how Here & Now enhances awareness of place-based community information, and how aggregating nearby Here & Now records broadens people's sense of place-based interactions throughout the community (Carroll, Hoffman, Hanet al., 2015).

The focus of Here & Now has been codifying and sharing feelings, meanings, and experiences. But this same service can also be quite utilitarian. For example, a photo of a pothole calls attention to the need for road repair; a photo of a sale in progress at a local store could draw customers; a photo of citizens debating a policy proposal may become part of the local news.

Heritage Lives in Places

The fleeting, ad hoc, but rich personal experience of local places that grounds the here and now of everyday life, is complemented by the history and heritage of these same places. Many places we pass now served as other places in the past. Construction sites are an obvious example; they are in the midst of becoming a new or refurbished place. A few famous spots in a city might have a plaque briefly citing a particularly notable former resident or purpose. However, most places remain silent and anonymous as to what they formerly were.

We have been studying how to bring the history of local places into the everyday lived experiences of citizens. Research has found that collective city memory (Ringas et al., 2011) – local knowledge, experiences, and people – can be leveraged as a source of empowerment that builds a city's social infrastructure (de Kreek & Oosterbroek, 2013). Working with the Historical Resources Commission of the

The Internet of Places at Community-Scale

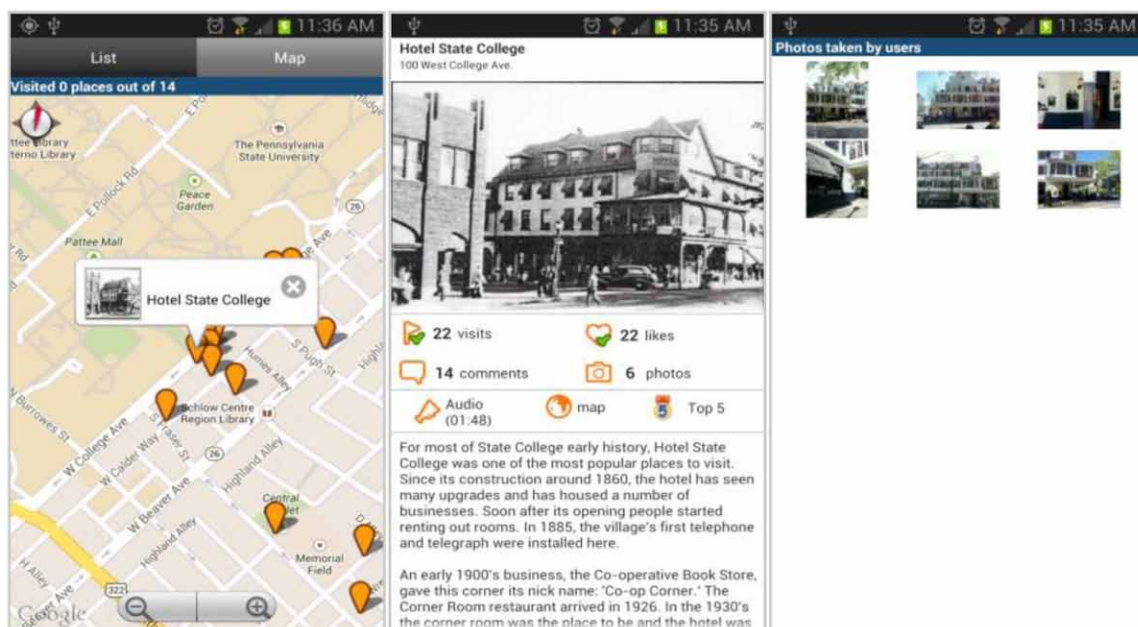
Borough of State College, Pennsylvania, we developed Lost State College, a map-indexed collection of self-documenting places (Figure 2). This service presents geo-coded photographs and other documentation for 43 historic buildings and 14 plaques in the main downtown area of State College. A person at one of these locations can view its record, including images from different points in time, the street address, textual and audio descriptions, and web links.

Lost State College also supports typical social media interactions such as visiting (check-ins), liking, commenting, and the ability to add one's own photo and caption to a place's history. Thus, at the same moment the user can engage with a place as it is now, but also engage depictions and descriptions of the place as it was in the past. The service was called Lost State College because the history of community places can be lost as it is overwritten by successive renovations and rebuilding. In this sense, the present obstructs engagement with the heritage of local places, and by so doing might undermine a sense of community identity (Carroll & Rosson, 2013; Hester, 1993).

The place histories curated in Lost State College can be accessed through an interactive map in a desktop computer, but we have been particularly interested in mobile access at the place itself, because this allows places to speak for themselves directly, presenting both their history and their embodied present to as the person is there. Being there also affords personal interaction with a place, walking around its current embodiment, and using social media interactions to explore its digital history.

After building the Lost State College mobile app, we studied local residents as they took a pre-scripted "tour" of a set of popular downtown places. We wanted to see how they interacted with the application, and hoped to understand not only their moment-by-moment usage behaviors, but also how the layers of content grow through users' posts about landmarks, paths and personal reactions and suggestions (Han, Shih, Rosson et al., 2014). Overall, we found that participants used Lost State College to both access

Figure 2. Screenshots of Lost State College: Map view (left), detailed view of the historical landmark (mid), and a list of photo taken and shared by participants (right)



official historical information and to augment the stories and personal experiences with places. The contributions and interactions from participants did indeed add a new layer to the places, transforming them into more meaningful and interactive local places that will be appreciated by both local residents and the community.

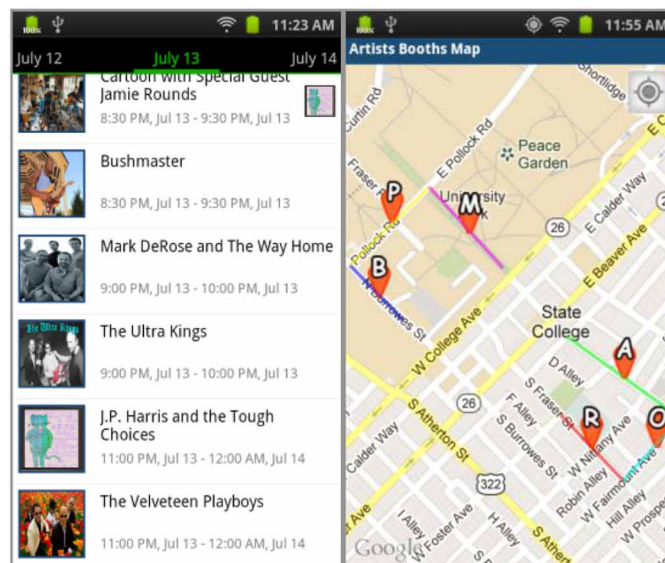
Place-based heritage preservation and sharing, as in Lost State College, illustrates hyperlocality: The place information is itself placed, that is, accessed by GPS coordinates; it is experienced in the place to which it refers. The integration of past and present within Lost State College also extends the notion of hyperlocality to include temporal layering of a place (though terminologically, it is not clear where one can go beyond “hyper-”).

Places Integrate Activities

Experiencing the IoP at the scale of a community enriches people’s activity by connecting it to community feelings, opinions, and events, and to other individuals in the community. Within this framework, places “speak” for themselves, sharing the experiences and history that they have hosted; however even more than providing a record of activities present and past, local places organize and integrate community events. Places need not simply serve as a locale for events; their structural features can be used as a rubric for how an activity will take place.

As an example of using place to integrate community activity, we have experimented for several years with an Arts Festival application for the Central Pennsylvania Festival of the Arts, held annually in State College, Pennsylvania (Ganoe et al., 2010; Hoffman, Robinson, Han and Carroll, 2012; Shih, Han & Carroll, 2015a), an extensive art, crafts and music program typically attended by about 125,000 individuals, a mix of residents and visitors. In the application, festival events are presented both as a list view and in a map view (Figure 3). The latter is an example of how places can organize activity.

Figure 3. Screenshots of the Arts Festival mobile application for community information and events: A list of festival artists (left) and festival booth locations (right)



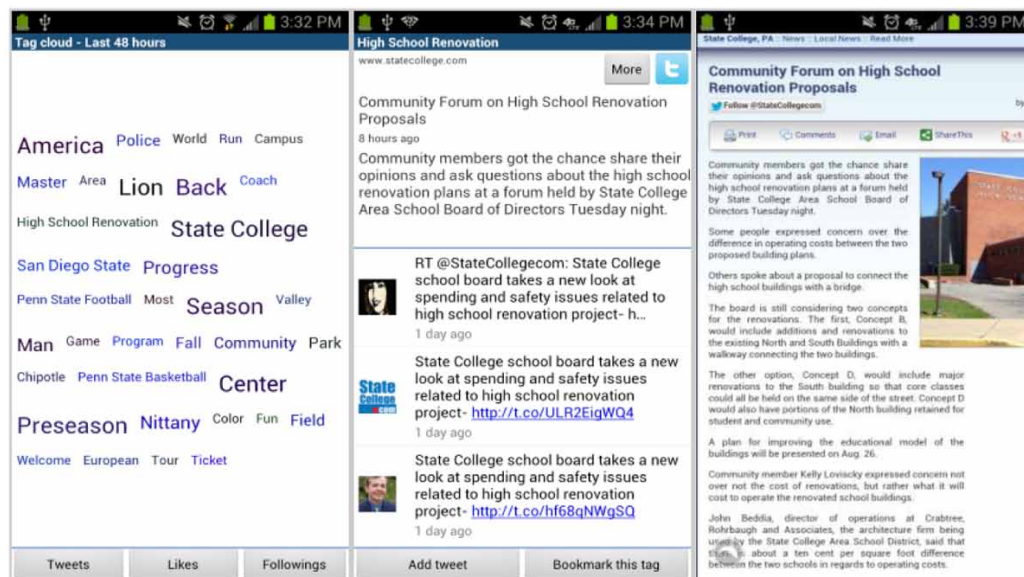
The Internet of Places at Community-Scale

We are also exploring how places at a coarser level of granularity, namely towns rather than buildings or streets, can provide an organizing framework for community behavior. The Local News Chatter application (Figure 4) has the goal of improving citizens' awareness of their local news, enhancing feelings of community engagement, and attracting online social interactions about the news. The core concept of Local News Chatter is to aggregate information that is of local relevance from multiple sources, and to provide supports for tweeting or commenting on the local news thus presented (Han, Shih & Carroll, 2013, 2014; Shih, Han & Carroll, 2014a, 2014b, 2015b). The sources include formal articles from local media and microblogs (e.g., Twitter).

Local News Chatter presents a tag cloud view of local news items. The tags are extracted through linguistic analysis of the news stories, with the cloud is formed to include both high frequency and low frequency words and phrases. In the cloud view, larger tags indicate popular topics; smaller tags imply lower popularity. Local News Chatter conducts a similar analysis on Twitter posts with local coordinates, combining the resulting tags with those culled from local media stories. By leveraging existing content in this way (i.e., news and tweets), the application takes a sort of “jumpstart” on adoption, for example compared to a novel news chatter tool that must build its own content. This aggregation of content (the tags serve as an index to the original stories and microblogs) helps to orient viewers, promotes a sense of “the local buzz”, and is a starting ground for news discussions.

Citizens who tried out Local News Chatter in laboratory studies (Han, Shih & Carroll, 2014) generally offered positive feedback on the cloud overview and the detailed view of twitter posts about the news. The cloud view helped providing a quick overview of all local news and what is going on in the community, and was seen as especially helpful for guiding attention to less popular news. The aggregated tweet view encouraged users to comment or tweet their own opinions. Microblog posts are normally

Figure 4. Screenshots of Local News Chatter: A tag cloud presents the overview of the most recent trend of local news (left), the combined view of formal news articles and socially generated tweets (mid), and a more detailed formal news information (right)

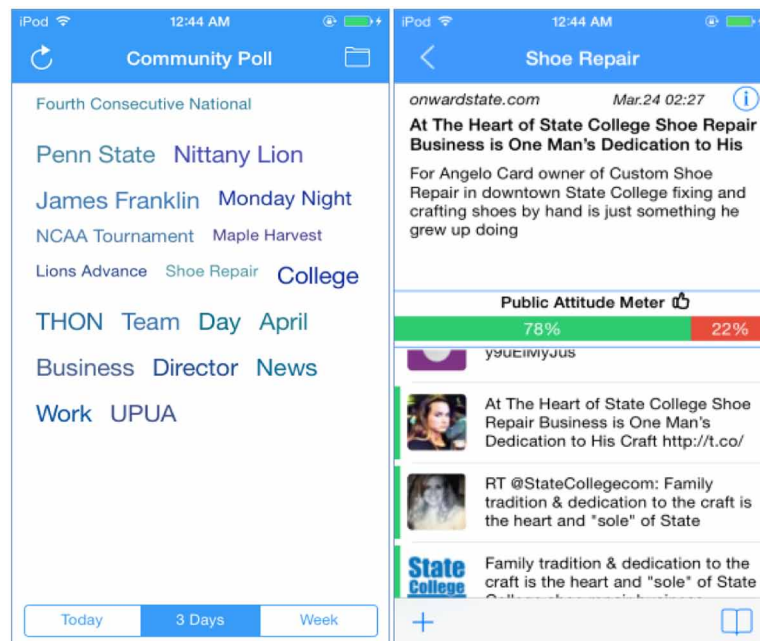


personal whereabouts information that chronicles an individual's daily activities. Any given post can be very interesting to some readers, but annoying to others. We found that connecting local tweets to local news stories in an integrated fashion created new opportunities for routing useful microblogs to local residents.

To further explore the user experiences afforded by Local News Chatter, we added a Public Attitude Meter (Figure 5). This widget calculates a "community sentiment" value by using a sentiment analysis algorithm to analyze the polarity of public opinions as conveyed in tweets about local news topics (Shih, Han & Carroll, 2014b). If the meter score is positive, a thumbs-up icon is displayed next to the text; if negative, a thumbs-down icon is shown. Each individual tweet also reflects a positive or a negative attitude: positive tweets have a green bar and negative tweets have a red bar next to the user profile image. In a user study, we found that when residents are made aware of public sentiment they feel encouraged to read local news articles and participate in social media discussions.

Our next step is to investigate how this tool would be used and adopted by a local community. We also intend to investigate the influence of smartphone affordances (such as mobility and accessibility) on reading, creating, and sharing local news information; we hope to understand people's expectations about whether and how such technologies can keep them up to date and in touch with local news, events, and activities. We are also working to extract more precise location information from the news stories and microblogs, so that we can present news content that is tied to where a user is currently located.

Figure 5. Screenshots of the added Public Attitude Meter that represents community sentiment based on sentiment analysis



Places Engage Interaction

In the 1980s, Oldenburg (1989) introduced the concept of third places as social environments that are separate from home and workplace, but essential to building civil society, democracy, and civic engagement. Third places have been co-opted by nomadic workers, who tend to work in separation at their laptops; this working style is often experienced as unwelcoming to social interactions with others. This is ironic and unfortunate because it replaces the potential for civic interactions in third places with further examples of isolation and self-imposed siloes.

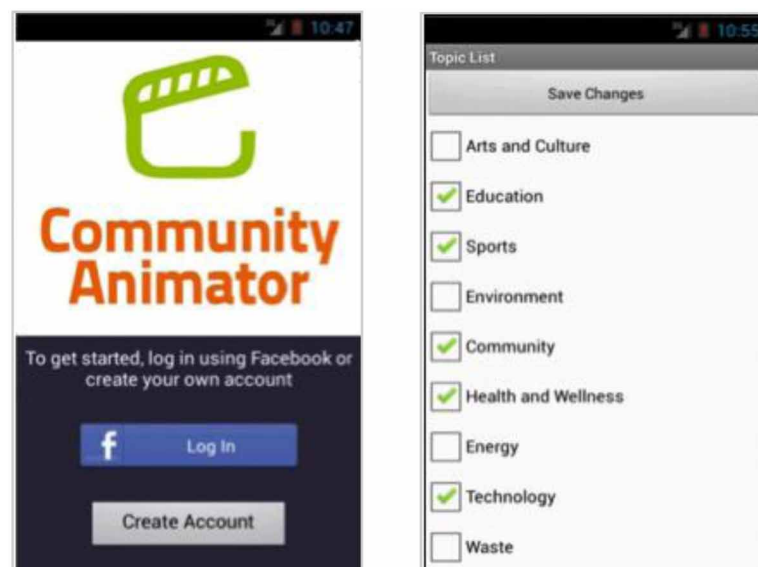
Community Animator (Figure 6) introduces new opportunities for social interaction by allowing individuals to self-characterize their community interests and activities, and indicates through an opt-in dialog that they are available for face-to-face chatting (Carroll, Kropczynski & Han, 2014). Users who choose to opt-in are matched by a combination of current physical proximity and shared community interests.

Although this application is still in development, the following scenario illustrates how Community Animator might be used:

John attends a public meeting about changes to a local housing ordinance and did not feel knowledgeable enough to provide public comment at the meeting. After the meeting, he leaves the municipal building and walks to a coffee shop across the street. He is motivated to continue talking about the ordinance and gain perspective of how the changes will affect others in the community, but as he looks around the shop, others are sitting with laptops wearing headphones or appear to be intent on cell phones and tablets.

John logs into Community Animator and selects the topic of housing. He is then introduced to someone sitting in the back of the coffee shop that is interested in the same topic and is open to conversation even though he previously gave the appearance of looking busy. John then spends his lunch sharing what he

Figure 6. Screenshots of Community Animator: A list of community issues (right) is used to characterize one's interests in order to initiate discussions with other residents while in public places



just learned at the public meeting with another community member, and their shared understanding of the changes reveal that the ordinance may be more harmful to the community than helpful. At the next public meeting that John attends, he is able to provide a more descriptive account of how these changes may adversely impact others.

Future research on Community Animator will explore mechanisms for preserving conversations in a low-effort manner, so that important community discussions can be shared with a wider audience. This initial work will simply work to identify how these community interactions can create shared trust, collaborations, and a “win-win” culture for divergent or siloed groups. The results of this project will provide information that is useful to both researchers and community practitioners. Using geo-location data of where the mobile application is accessed, we will be able to identify and celebrate community buildings that are most often used as third places by community members.

Informed discussion among citizens is essential to democracy. Broad participation in civic discussion is both more feasible and more important for democracy in community scale. People are more engaged in communities when they feel that their participation can make a difference, and conversely. Local government and local civic deliberation have always been place-based; typical issues are planning and zoning of neighborhoods, commercial districts or other functional regions within a town, development and maintenance of services and infrastructure that is placed, like roads, sewage lines, parks, buildings, and so forth. It is already the case that interactions in the public sphere now are often carried out online through websites, forums, and emails.

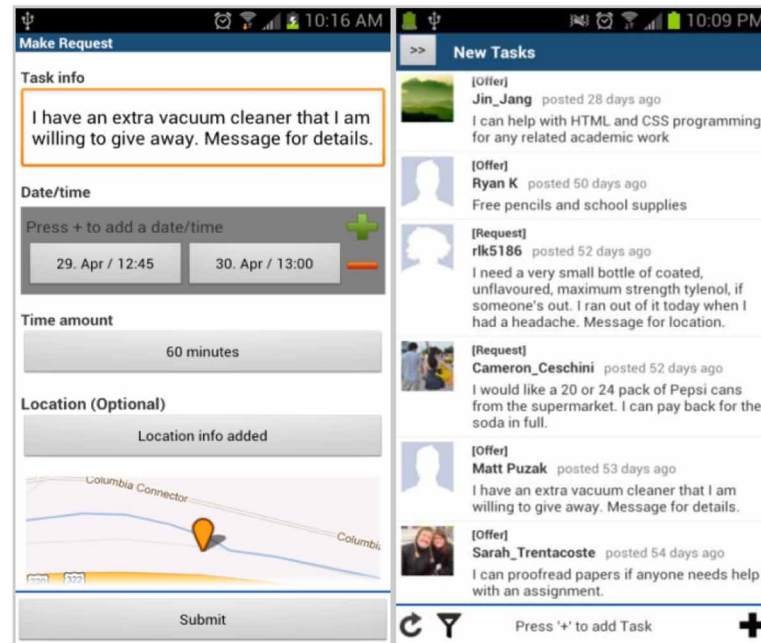
Community Animator provides a new way to encounter fellow community members, participate in the local community, and act on collective impulses. A related example is Mobile Timebanking. Timebanking is a community exchange system where people contribute services to the community valued on the basis of the time it takes to perform the service (Cahn, 2000). The person who provided the service is entitled to receive that amount of services from members the timebank. This is strongly equitable basis for exchange, and has been found to strengthen communities, as well as to enhance personal efficacy and self-esteem (Seyfang, 2004; Shih, Bellotti, Han & Carroll, 2014).

Mobile Timebanking moves the timebanking interactions to a smartphone platform; by tying the interactions to a specific time and place, participants have the opportunity to make more fine-grained exchanges. Consider possible scenarios such as “My son left his history book at school today (Mr. Smith’s room); if you are picking a child up could you get it for me?” or “I forgot to get milk on the way home; if you are stopping at the local grocery store, could you get me a ½ gallon of 2%?” Supporting timebanking activities with a mobile application allows these exchanges to address time and place-dependent needs and interests (Han, Shih, Bellotti & Carroll, 2015). Such requests can be seen as possible future place-based events; actually, each has two local place references: the place where someone needs a service (the school, the grocery store), and the person’s current location (waiting for the service).

We are currently exploring the opportunities and potential benefits of mobile timebanking. We have designed a mobile timebanking application that supports core functionalities such as posting or accepting tasks or services, reporting completed tasks, giving time credits, and viewing a task history or a user’s profile details (Figure 7). To take advantage of smartphone capabilities, the application has been also designed to support more functionalities that are suited well in mobile computing such as having a map view that shows both user’s location and task locations posted by other local residents as well as providing a notification feature which allows users to receive a notification for any incoming text messages from others or status updates of the tasks in near-real time at any locations.

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Figure 7. Screenshots of Mobile Timebanking for community volunteer exchanges: Add a task page (left) and a list of tasks requested and offered by participants (right)



In a five-week field trial, mobile timebanking was easily adopted and clearly leveraged the affordances of mobility (Han et al., 2015). During the trial, participants were able to add geo-coordinates to tasks they posted, which allowed others to access tasks based on their location, and in some cases was a specific inducement to accept a task request. This mobile timebanking app is now incorporated into the hOurworld timebanking group, with more than 400 affiliated local timebanks and 28,000 members as of February 2015. There exist great research opportunities to understand how timebanking members utilize mobile technology in exchanging timebank services and articulate the benefits and challenges of mobile timebanking in the near future.

Places Are Governed

IoP raises possibilities for cultivating democracy at the level of individuals, which is through the informal, public practices that de Tocqueville (2003) called “habits of the heart”. Thrift (2004) argues that affect and political discourses and their formation should be treated as an integrative part of a city rather than a separate process apart from the city’s infrastructure. IoP also presents new affordances for local government. Korn, Matthias and Back (2012) found that places can encourage expression and communication of memories, feelings, and attitudes, and that sharing emotions in this way may promote civic discussions relating to geographic areas in neighborhoods or communities. Indeed, Lost State College was inspired by a design concept first described by a local town official, and the Historic Resources Commission, an agency of the municipal government, provided much of the non-social content presented.

Communities as places are fundamental social units where members have keen interest in taking collective actions and addressing the conflicts arise from the multiplicity of practices, beliefs, and needs. Place-based communities form the bedrock of a democratic society: to be a high-functioning social unit, political participation and civic engagement must be practiced at all levels of public decisions – whether economic development, standards for community behavior, maintenance of shared infrastructure, or law enforcement. Democratic governments depend on the engagement and participation of their members, and IoP can aid governance by improving participation and engagement in local political discussions and decision-making.

An important positive attribute of community is that the members cooperate; healthy communities practice sustained care and concern for one's fellows (Yuan, 2002). Cooperation in turn presupposes effective communication. Often a community is small in number, perhaps comprised of people living in close physical proximity, as in a neighborhood, village, or town. Such communities find it easier to engage in participatory and deliberative democracy, due to physical proximity to others and the likelihood of sharing of common experiences and perspectives through encounters and conversations. Democracy in local communities can be a lived-in experience, and the desirable conditions of democratic practice tend to be found in the social relations of the local community (Smith & Blanc, 1997). There is ample evidence that community-based action has occurred in a wide variety of cultures and is universal (Castells, 1983)

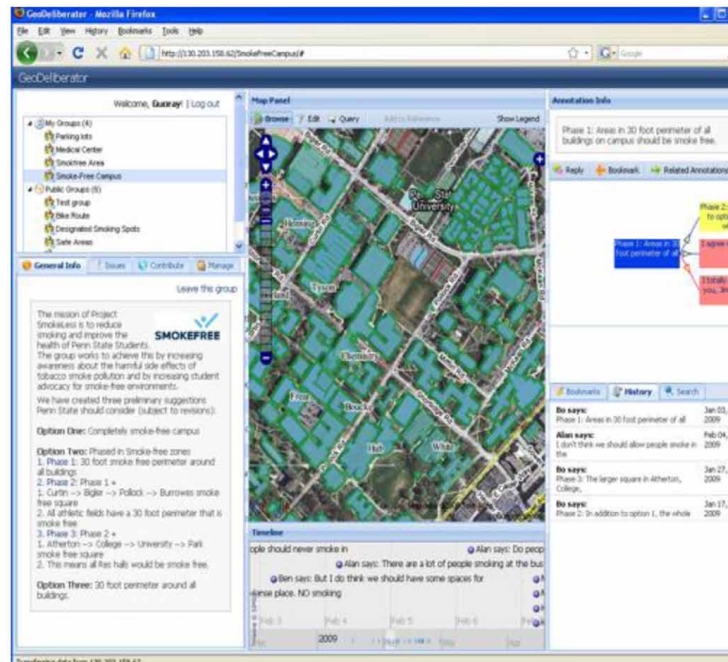
In cases where close proximity is not possible, or informal personal interaction is not typical, social media and geospatial technologies may help to support the communication and sharing needed for joint action. However, the simple provision of such tools is not always enough, for example when topics and opinions depend inherently on the spatial structures and relationships within a community (e.g., a set of streets, intersections or buildings). In such cases a democratic community may benefit from a more elaborate integration of the shared concerns with the associated places.

To explore this possibility, we are developing the GeoDeliberator (Cai & Yu, 2009; Kropczynski, Cai & Carroll, 2015), an online tool for place-based deliberation. Figure 8 shows a prototype of the tool that introduces spatial language concepts into deliberative dialogues offered to community members. The tool incorporates techniques such as geotagging, geoannotating, and geovisualization to meet its design goals. Using the GeoDeliberator, a community can organize multiple parallel deliberation forums, where each forum presents a unique mission or issue to be examined collectively by the participants. Forum members can view a set of relevant documents together, and can also identify, annotate, and question the information nuggets. The forum information and community conversations can be accessed through geospatial, timeline, and conversational thread views, providing multiple overlapping perspectives on the same set of issues. The tool is designed to enable considered opinions to be expressed, contrasted and synthesized as collective opinions consistent with the principles of deliberative democracy.

A related system is the Future State College project, designed to engage residents in discussion of master plan frameworks that municipal governments develop to guide local development over the long term (10-15 years). A master plan includes many detailed sketches and other images of future streetscapes. Our partners in the city government told us that citizens often have difficulty understanding the plans and seeing the future environments in context, and that this is an obstacle to more effective participation in local government planning processes. We worked with the government of State College, Pennsylvania, to organize documents and imagery from their planning process and make them available through a mobile application. Thus, analogously to Lost State College, a resident can examine representations of the future plan for particular locations in the town while visiting and experiencing those places (Figure 8).

The Internet of Places at Community-Scale

Figure 8. GeoDeliberator's User Interface: (1) Group Panel, (2) General Panel, (3) Map Panel, (4) Timeline view, (5) Annotation info Panel

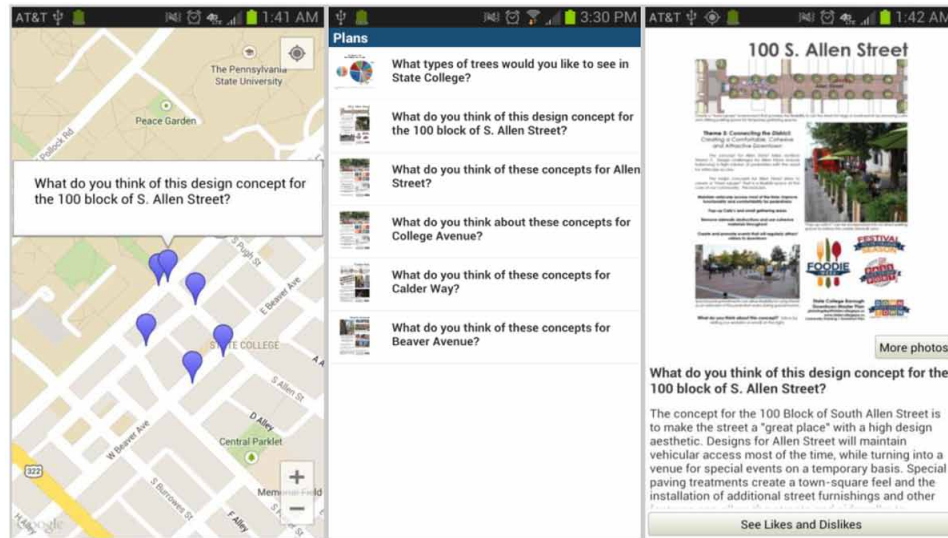


We are now designing the mobile application called Future State College, which has a similar rationale of Lost State College with respect to increasing civic awareness and participation but using different content (Figure 9). We are striving to give local citizens easy access to the master plan, specifically the parts of the plan tied to their current location. Our municipal partners hope to collect feedback and comments from local citizens and see their reactions and thoughts in a simple and integrated fashion, which could also be considered and discussed in planning processes. In this sense, we have implemented a simple voting and comment interface to the application. More specifically, citizens can up-vote or down-vote on the plan, add their own comments or read others, and like or dislike others' comments.

The simple and easy-to-use Future State College application will benefit both citizens and the municipal government. From a citizen's perspective, it will be easier to stay aware of future plans and express and share thoughts with other citizens as well as the government. From the government perspective, officials will be able to see how their constituents think about the plans both in general (the up- and down-votes) and more specifically (their more detailed comments). The Future State College application is another example of making place-based local community information and interactions more visible and accessible through mobile technology.

Overall, IoP allows us to directly integrate civic behavior with the community places to which the behavior refers. IoP can involve the posting of official information maintained by the municipal government (including requests for public comment), but it could also include the sharing of informal and ad hoc thought and experiences of citizens (Here & Now), historical context about places and their surrounding locales (Lost State College), local events and volunteering tasks or services that are occurred at or are scheduled to occur at a place (Arts Festival and Mobile Timebanking), face-to-face conversations about

Figure 9. Screenshots of Future State College: A map view with the plans presented as pushpins (left), a list of the plans (mid), and a detailed view of the plan (right)



local issues in third places (Community Animator), online community discourse for local news, events, and activities (Local News Chatter), and local future plans tied to different places (Future State College).

Once a place is regarded as a container for digital content, it invites related content, for example comments or discussions contributed by people who visit the online place. A person having coffee downtown might browse and even contribute to a debate about road construction that is causing traffic jams outside the window (Carroll & Rosson, 2008). This kind of scenario further integrates and leverages hyperlocal information and interactions while also potentially making local civic deliberation more sensitive to actual users and experiences of community services and infrastructures.

The use of community places to organize community events and activity, including civic deliberation, is a proactive application of IoP. The mobile applications we have described enhance awareness of and interest in community places, reinforcing both community identity and willingness to participate, two of the defining principles of community itself (Cahn, 2000; Carroll & Rosson, 2013).

DISCUSSION

Although Internet technologies have richly interconnected our world, they are only now becoming integrated with that world – in the Internet of Things. Much of daily life is still lived within geographic locales – in place-based communities. Information and interaction challenges in community-scale are distinctive and critical: Local community information, examined source-by-source, is sparse in many communities. Local newspapers, nonprofit groups, businesses, bloggers and forums each generate relatively few local news items, posts, etc. in comparison with national news and entertainment feeds. Analogously, local community interactions online, examined site-by-site or service-by-service, often fail to exceed the threshold of community perception, because there tend to exist few posts and even fewer comments in online local space.

The Internet of Places at Community-Scale

IoP at a community scale is more than a corollary of the IoT plus GPS technologies. It is the project of leveraging better hyperlocal participation in and access to the meanings, activities, and emotions of community places. This is not an inevitable given of information technology in general, or of the IoT in particular. Rather, it is a critical alternative toward which we can orient and progress.

We have presented a set of prototypes, interaction scenarios, systems, design analyses, and empirical studies. These prototypes illustrate possibilities for aggregating and presenting the feelings people have about the places they live in. Here & Now makes visible the beautiful but mundane experiences of everyday life. It integrates Hester's concept of sacred places with the flow of lived experience, raising the possibility that the sacred structure of a community is dynamic, and constantly negotiated through life experiences.

Indeed, Lost State College illustrates how part of a community's sacred structure is being constructed constantly through the experiences and activity of people. This application juxtaposes the past and present of sacred places throughout the community, and invites people to experience and share. History is remade every day, because the present is the reference point, and is always changing. This is easy to miss when the history of most sacred places is masked by the present, and not embodied with it.

The IoP at community scale enriches community activity by connecting people to feelings, opinions, and events, and to other people. For example, Local News Chatter aggregates information sources in a new way, to emphasize the connection between a local public event or topic, something that might have been described in mass media, and the personal reactions and insights neighbors have to that event or topic. It connects people to the experiences of the community, and directly to others, people whom they may yet not know or know well.

Mobile Timebanking and Community Animator are examples of new kinds of community interactions enabled by IoP. Mobile Timebanking enhances awareness of opportunities to help and to be helped by nearby others as one moves through the community. Making needs, interests and abilities more visible, and matching them on the fly, could mutually leverage resources and opportunities. It could change the modern experience of being out in public toward less anonymity, more engagement, and the constant possibility of meaningful happenstance. Similarly, Community Animator allows people to make themselves available for discussions about community themes and projects. This concept can make any public place into what Oldenburg (1989) called "a third place", where citizens engage on an equal footing.

Beyond personal and informal place-based experiences and interactions, the IoP should facilitate and enrich public life. The GeoDeliberator presents local citizens an online forum to debate about public policy choices, facilitated by a spatial perspective (through maps and visualizations) on facts and analysis drawn from public policy documents, and statements by subject-matter experts. This project also emphasizes the value that citizens can provide to such discussions by creating paths and summaries of investigation on issues in a way their fellow citizens could use. One premise is that complexity of information spaces, even for municipal issues, is complex and poorly organized, and that citizens do not know where to begin or what to do to make a difference.

Another example of how IoP at community scale can address the public sphere is Future State College. Citizens can view and comment on various depictions of the future plans for a local place, which physically visiting that place to help image the consequences of planned developments. The premise of this prototype is that by embedding the plans in concrete contexts of community places will make the plans more understandable, and more interesting to citizens.

As is often the case, the primary purpose of design prototypes is to evoke further ideas and better ideas. In that sense, this set of prototypes is not an answer to the question of the IoP at community scale, but rather move us a step toward better framing the question.

IMPLICATIONS

Socio-technical innovations always have both direct and indirect effects. Direct effects are shorter term, and often intended. Indirect effects often take more time to become apparent, and are frequently unintended consequences. As described, the direct effects of the Internet of Places at community scale are place-based experiences and interactions that are socially and emotionally richer, more meaningful, and perhaps more effective for the people who live together in a place and increasing the sense of place attachment (Lewicka, 2011).

Considered as a critical alternative, the IoP at community scale also might entail broader, longer-term, and less direct socio-technical consequences. One such consequence might be that newcomers could more easily come to know a neighborhood or town they moved into, both its places and the experiences, interactions and activities that give those places their meaning. This is most basically a learning and access implication: Visitors and newcomers might be able to learn much more about communities through visiting their places. Marginalized and peripheral members of a community might more easily move toward the center. Public backtalk about public places might ameliorate one of the least attractive consequences of close, place-based community, namely, that of insider versus outsider. If it were easier to understanding what is going on in a community, what places mean to the members of the community, what events takes place and with what significance, etc. then it might be much easier to become a member of the community, and to more easily pass from the outside to the inside.

Another consequence might be enhanced mindfulness. Enriching various places with signature experience, memories, issues and discussions, and plans for the future would make it harder to turn off attention, to be inert as to where one is. The broadest way to view this is as affording a more mindful human experience, a way of living in which one is more aware of one's own thoughts and feelings moment-by-moment, more aware of others, and just awake to life. More narrowly, IoP might at least make us specifically more mindful of our own neighbors, neighborhoods, and communities, more aware of the now-invisible personal narratives and currents of emotion that constitute our local places.

Of course, as cities and communities are becoming more technologically-enhanced, there are numerous privacy implications when sharing personally-identifiable information that could lead to untended consequences. Misleading, false, or biased information may perpetrate escalation of public hysteria and social bubbles that may be difficult to overcome. There is also the potential of over-sharing, and it might be that people need the down time of relative anonymity and isolation, and that places sharing feelings, reminding us of community heritage, and updating us on local news, opinion, and issues would overwhelm us.

We are optimistic about the potential upsides of enhancing access to and engagement in local places for increasing participation in local community matters. In all of our projects we have encountered great interest in knowing more and sharing more. In many cases, community members don't know how, when or where to start, and often vastly underestimate how much they already know and can contribute even though the opportunities are literally all around them (Carroll, 2012; Carroll & Rosson, 2013). In our case studies, we anchor community history, news, events, interests, and discussions to geospatial maps

that are open for participation among local community members and external visitors. IoP creates digital third places of discussions that could connect citizens with shared interests and further strengthening community identity, membership, and presence (Carroll, Shih, Hoffman, Wang & Han, 2014), and this is evident in almost all of the case studies (e.g., Community Animator, Local News Chatter, Community Poll, Lost State College, Future State College, etc.).

The Berkeley Community Memory was the starting point of a sociotechnical movement eventually called community networking (Schuler, 1996). In information technology, we confront new challenges and opportunities regularly; each is a possible new starting point. In this paper we described our investigation of an extension and specialization of the Internet of Things, one we call the Internet of Places at community scale, as an initiative in community networking in the long thread of research and development inspired by the Berkeley Community Memory.

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Chapter 2

The Fermentation GutHub Project and the Internet of Microbes

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ABSTRACT

The Fermentation GutHub is a local community of fermentation enthusiasts in Singapore formed around 'smart' human-microbial interactions. The project is a critique of the common IoT utopia claiming efficient and transparent interactions between citizens and various stakeholders using smart sensors and monitoring devices in the cities of the future. Instead of relying on technology produced and supported by corporate actors or large government plans, the GutHub scenario uses existing fermentation groups and DIY tools as a model for designing resilient and symbiotic urban communities. Against the utopia of evidence-based decision making driven by policy and corporate actors, it emphasizes the importance of collective experience with risk and opportunities negotiated on a grassroots level. The project supports citizens' exchanges of various cultures, fermentation practices, and sometimes dangerous but also beneficial experiments with our guts as an interface, and proposes a model for messier IoT scenarios of future cities.

INTRODUCTION

The Fermentation GutHub is basically about fermenting everything around and making wild associations to post-socialist foodies, Latour, Stallman and bitcoin.

The Fermentation GutHub is a personal and social experiment with food, taste and health, but also a platform for online - offline exchanges of fermentation skills and starter cultures (microbial mediums used for activation of the fermentation process). Through the GutHub project, we probe ideas of various

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new technologies and paradigms (blockchain, open hardware) to support local DIY food production, and highlight the related issues of trust in peer sharing economies. It is also a response to the present IoT (Internet of Things) scenarios (Ashton, 2009), in which corporate and government stakeholders try to define the future of urban communities and propose ‘smart’ models of an ideal society.

The Fermentation GitHub was initiated in April 2015 by four food-tech enthusiasts at the National University of Singapore (including authors). Since then, the project has been operated by an evolving community of geeks and foodies gathered around two Singaporean community hubs, the Hackerspace.sg (Hackerspace.sg, 2015) and the Edible Garden City Singapore (Edible Garden City, 2015). The Fermentation GitHub, as its name indicates, is a “git” platform to manage exchanges of fermentation skills and resources instead of software code. The platform includes a “Fermentation Bank” of starter cultures in a form of a public refrigerator; a Github page serving as a repository of fermentation ‘source codes’ (recipes; how-to tutorials); an active Facebook group for troubleshooting and sharing of fermentation ideas; and some OSHW (open source hardware) tools, such as the “Mother 0.1” starter culture incubator.

The GitHub project tests various HCI (human-computer interaction) scenarios transgressing anthropocentric limits and embraces technologically mediated human-to-bacteria interactions. In this sense, it is an example of situated and everyday techno-science practices, which create “assemblage of neglected things” (Puig de la Bellacasa, 2011) and support human and non-human entanglements (Barad 2007; Haraway, 2003), which are gaining momentum in the recent feminist technoscience (Mol, 2002; Tsing, 2015). We specifically build on the notion of non-human “hyperobjectivity” (Morton, 2013) that operates on scales bellow and above the human body and horizon, and shows some larger environmental issues.

The practices of food fermentation connect the embodied knowledge of rural and folk culture with food science, thereby addressing some common themes in food studies, such as food preservation; food sustainability and security, the authenticity of traditional cuisines; and the industrial “engineering” of new food tastes. We see the GitHub as an example of a technological folklore rejuvenating the traditional food practices through tinkering with low-cost DIY technologies, inspiring anyone to learn and perform simple food science experiments at home. Along with the project, we are collectively building an urban community, which works on its immune system by sharing and fermenting food and engaging in sustainability-oriented research. As a platform supporting local food production and community building, it also stresses the importance of including food, bacteria, yeasts, and other non-human actors in our thinking about the networks that define the cities of the future.

Based on the observations from our GitHub workshops, meetups, and other community activities, we propose the technology-enabled microbial interactions as a model for negotiating a relationship between different actors and stakeholders, while highlighting the notion of empathy, symbiosis, and mutualism (Schmitt and Holbrook 2003; Bronstein 1994). In this sense, our study is a contribution to the emerging field of “food informatics” (Choi, Foth, and Hearn 2014; DiSalvo 2012) extending the issues of IoT food traceability to the issue of peer culture and design supporting human and non-human networks (or interaction with hyperobjects).

BACKGROUND

Urban Foodies Cultures

The mass commercialization and standardization of food production practices have resulted in the homogeneity of the taste of processed foods, as well as in the destruction of local food cultures. Coupled with the growing food scares and health concerns about the additives in processed foods, these processed have caused a growing interest in using alternative food sources and artisanal methods of food preparation (Harvey, McMeekin & Warde, 2004). Citizen-driven food initiatives promoting sustainable food production, such as the local food “locavore” movement (Prentice, 2007), or various food co-ops and neighborhood food swaps have emerged all over the world. These citizens’ reactions to the unfolding industrialization of food practices bear activist potential, sometimes embracing rather radical DIY strategies and techniques. Among these DIY efforts, there are, for instance, active groups of biohackers designing their DIY vegan cheeses (Real Vegan Cheese, 2014), or amateur groups of “diet hackers” reverse-engineering their meals into nutritious powders to save their guts as well as those of the Planet (DIY soylent, 2014). These movements emphasize the importance of peer- learning and direct hands-on involvement with food production over the de-personalized human-food interactions performed at the supermarket cashier counters.

In many ways, the interaction of citizens around food shows more clearly the future issues and opportunities related to the scenarios around IoT and resilient, smart cities, as it combines new scientific knowledge and technologies together with traditions and local cultures. Existing smart city scenarios are highly connected to issues of resilient food production (Food Smart Cities for Development, 2015); however, the citizen-driven food sustainability efforts are often ignored and eclipsed by governmental and corporate embracements of food traceability. The existing smart city plans fail to recognize the potential of DIY food efforts, which are often seen as too decentralized, ‘messy’, and risky (Dolejšová, Lin Kaiying; 2016). Home fermentation, which is one of the oldest food production and preservation techniques known, represents one of these DIY efforts and is experiencing a revival in the contemporary artisanal food movements.

At the heart of the fermentation revival is a DIY food activist Sandor Katz (2012), who advocates fermentation as a way to “break the confining and infantilizing dependency of the role of consumer, and taking back our dignity and power by becoming producers and creators” (p. 17). Home fermentation with all the DIY practices involved is indeed a messy food practice; however, the empowering opportunity to become a self-contained food producer is worth all the (delicious) messiness. This ambiguity offers an important model to rethink the technologies behind the present IoT scenarios, which usually promote strategies based on safe, ‘clean’, and well-organized decision-making guided by few powerful stakeholders.

Fermentation: Interaction as Symbiosis

Food and beverage fermentation, a metabolic process that converts sugar to acids, gasses, and alcohols using microbial organisms, has been used since the Neolithic times (Harley, Klein & Lansing, 2006). The fizzy reactions of bacteria, fungi, yeasts and other microbial cultures that produce the prickling sour taste of delicacies such as kimchi, yogurt, soy sauce, or kefir, are favored by humans of all continents (Katz, 2012). Fermentation is usually associated with DIY at-home practices involving cloudy and messy mason jars, but it also comprises the foods commonly found in grocery stores, such as cheese,

bread, wine, coffee or chocolate. We often identify the fermentation practices with rural rather than urban context and with traditional culture rather than food science; a relation that has, however, begun to change in the recent decade (Lockie 2002; Fine 2004).

Fermentation makes food delicious, but also nutritious and potentially beneficial to human health, as it can help enhance the human immune system, reduce a risk of certain cancers, and improve digestion (Parvel et al., 2006). The restorative power of probiotics in fermented foods and beverages was discovered by ancient traditional healers and further passed on to citizens. The practice of fermentation comprises of unique knowledge and techniques that vary from one family (community, tribe) to another. There are no standards, best practices, exact quantities or combinations of ingredients – just ideas, recommendations and heuristic principles validated by human common sense. This DIY heuristics enables for impromptu experiments that convey a certain degree of freedom. However, similarly as with any other DIY amateur practice, this freedom also entails certain risks. The fermentation DIYers need to take a good care of their jars and know some basic principles of this traditional food craft to mitigate these risks and avoid ferment's contamination by undesired microorganisms and molds. Thus, DIY fermentation needs to be substantiated by a collective sharing of ideas and tips performed by active practitioners willing to mutually troubleshoot their work. In that sense, DIY fermentation represents ideal activity to test various forms of citizens' networking around food as a common domain of interest. Katz defines the home fermentation as a strategy involving "a broad web of connections" (Katz, 2012, p. 19), pointing out that individuals and households producing fermented foods can never be truly self-sufficient, and some form of exchange needs to be present to "broaden everybody's possibilities" (Katz, 2012, p. 261).

The main hypothesis of this paper is that also other grassroots collective strategies developed within the context of urban environment involve a similar degree of freedom and danger, which enables the participating citizens to gain true empowerment. The art of DIY fermentation, with all its risks and advantages, is a metaphor we want to propose for integrating data and technologies around IoT in the design of future cities, and use our project as an example of how this can work in practice.

Jars as Interfaces: Human-Microbial Interactions as a Model for IoT

The core element of the fermentation process are cultures – not only the sets of knowledge, beliefs, arts and morals that surround us, but also the "starter cultures", or so-called "starters". These are microbial mediums usually added to activate, speed up, and leverage the fermentation process by inhibiting the growth of undesirable microorganisms to favor the growth of desired ones. Starters such as whey or various yeasts have a transformative power, and the unique thing about fermentation is that it can be a self-propagating process, where the ferments continually feed each other. Brine from a previous ferment can be re-used as a starter for another ferment, which makes it a superfluous commodity, and an organic currency that, when treated properly, can be shared and maintained ad infinitum. If you take good care of it, the starter culture will grow steadily and make the jar bottomless, such as in the famous Czech fairy tale "Hrnečku vař!" ("Cook mug, cook!", Erben, 1967), where a young girl shares bread with a hungry old woman and, in turn, gets a magical mug that can cook an endless amount of porridge every day. However, nutritious ferments obviously do not grow out of the pure air, and an endless resource of self-replicating food remains a matter of fairy tales. Still, fermented foods are one of these value-added products able to transform the raw outputs of agriculture into stable delicacies via low-cost artisanal techniques (Katz, 2012). Moreover, as starters usually reproduce rather vigorously, the human caretakers are often willing to share them with others.

Therefore, the starter culture self-propagation offers a good model for sharing of IoT data in future urban communities based on more equal interactions between the lay citizens and stakeholders. The interactions around starters support mutual sharing of risks and opportunities, but also the awareness that there are forces and actors beyond the human scale, with which we need to create symbiotic relations. In the Guthub model, humans take care of their fermented jars; microbes take care of the jars' content that pampers the human guts; and the open hardware tools and online platforms make the communication process faster and accessible.

These human-food-tech networks involving the equal participation of humans and non-humans follow the paradigm of new materialism and object-oriented ontology, which promotes non-humans as active constituents of the world rather than mere utilities or accessories. The symbiotic trans-species collectives around fermentation embrace the ideas of cosmopolitics (Stengers, 2010), the Parliament of things (Latour, 2005), or the rhizome (Deleuze & Guattari, 1988) as models for complex interactions, which we can expect in IoT scenarios, where everything acquires an agency. In the case of DIY fermentation, these interactions represent a common everyday events accessible across age groups and social classes, involving foodies, homesteaders, makers and geeks, old aunties, as well as curious kids.

Community, Sustainability and Equality: Humans, Microbes and Hyperobjects

The DIY experiments with fermentation are driven by diverse motivations, such as the participants' desire for new taste experiences, a joy of tinkering, budget reasons, or concerns about personal health as well as that of the Planet. The fermentation practice resonates with the paradigm of locavores, i.e. people who prefer to consume food produced locally. The orientation towards local food sources and relative independence on the mass-market supply makes fermentation a sustainable form of food production supporting local edible "assets" within the global economic system. From the sustainability point of view, it is also a convenient way to preserve perishable food, such as milk, fruit, vegetables, or any surpluses of local, seasonable food harvest. Furthermore, the fermentation process usually does not require cooking and any electric heat processing, thereby offering an environmentally friendly food practice.

In this sense, we see the jars with bubbling ferments as a manifestation of hyperobjects, i.e. "the large-scale environmental objects such as global warming that transcend the spatiotemporal specificity of the human realm" (Morton, 2013). Hyperobjects are massively distributed in time and space and due to their hyper-scale dimension become invisible for a bare human eye, hence largely escaping the capacity of human imagination. The most common situations when we realize the existence of these hyperobjects are our interactions with their visible mesoscale manifestations, such as acid rains or, as we suggest here, the fermented jars. The rising price of food products, the incidence of GMOs and pesticides in mass produced foods, the growing food wastage, and other problematic issues in the global food production and distribution are all embodied by the mason jars of homemade ferments sitting in our home pantries. The jars thus alert us of nothing less than ecological dilemmas defining the age we live in and remind us of the lacking sustainability of the mainstream food system.

The communities of fermentation fanciers provide an interesting population to study when addressing the IoT issues, as they perform 'smart' grassroots exchanges of fermented foods and skills that transcend the 'proprietary' circulation of food commodities. These exchanges promote the notion of peer sharing economy and barter trades aiming to bypass the capitalist transactions.

P2P and Blockchain Fermentation Practices in the Sharing Economy

The concept of peer sharing economy is gaining popularity as a new alternative to the traditional economic systems dominated by supply and demand. The recent increase in demand for such alternative can be largely contributed to the consumer-operated services such as Airbnb (Airbnb, 2008) or Uber (Uber, 2009). Sharing economy is a term that encompasses all kinds of collaborative economic systems; however, a clear definition has not been agreed upon given the diverse forms of systems that can be considered (Reisch & Thøgersen, 2015; Schor, 2014).

Recently, Benita Matofska (2015) attempted to do so by defining sharing economy as “a socio-economic ecosystem built around the sharing of human and physical resources. It includes the shared creation, production, distribution, trade and consumption of goods and services by different people and organizations” (para 2). In a sharing economy, the participants play both the role of the consumer and the producer, or a “prosumer” (Toffler, 1980). The means of production can be made open and accessible to anyone who wants to produce independently on the commercial supply, be it individually or collaboratively. Through this collaborative work involving individuals of different social, cultural or professional background, the participants can innovate the agenda of various social and economic systems. Matofska even goes on to speculate that the peer sharing model will promote fair play, reduce inequality, and diminish poverty. The model thus coincides very well with the philosophy of alternative food movements, as it encourages consumers to take control of their everyday material transactions. The GutHub scenario utilized the idea and proposed a model of peer sharing economy for an alternative food community created around fermentation practices in Singapore.

Nowadays, people are still following the traditional models of fermentation sharing and exchange their starters and other fermentation resources on the neighborhood door-to-door basis. However, the contemporary urban lifestyle augmented by superfluous Wi-Fi signal and mobile broadband networks (which is typical of Singapore) opens a brand new universe of ‘smarter’ fermentation interactions. The technology-enabled initiatives for open peer sharing of food resources have already become a popular form of urban social bonding and entertainment. Such food sharing efforts encompass initiatives as diverse as an exchange of locally grown produce (Foodsharing, 2012), P2P distribution of cooking duties (Shareyourmeal, 2012), urban “2.0” farming (Sewon FoodLab, 2014), neighbourhood swaps of food leftovers (Leftover Swap, 2015), or even a leftover dating (Restdejting, 2011).

The enhancement of traditional fermentation practices with ‘smart’ technologies and sensors might sound contradictory to the idea of rediscovering the traditional food heritage. However, we aimed to show that within the urban context, these two strategies are not mutually exclusive. The GutHub attempts to connect both parts, i.e. the self-sufficient communal production of artisanal food, and the convenience of smart technologies, without a moralizing techno-scepticism. We aim to connect the paradigms of interactive design with the idea of local community, sustainability, and an enhanced sense of consumers’ economic independence. We started with organizing weekly fermentation meet-ups in the premises of our university department, and in January 2015 successfully occupied a classroom with a “no food & drinks allowed” sticker on the entrance door. After the initial literature review, we followed with an experiential DIY approach, and started to ferment everything around. Meanwhile, we talked about post-socialist times of food scarcity, spoiled millennial foodies, Latourian utopias, Stallman’s openness, blockchain future, as well as the painful unavailability of sauerkraut, cheese, wine or even a good tempeh in the Singaporean hawker centres and kopitiams.

THE FERMENTATION GUTHUB PROJECT FOR EDIBLE INTERACTIONS

Fermentation in Singapore: First Steps

Neither of us had previous experiences with fermentation - to adopt better hands-on skills before proposing anything to the larger Singaporean community of geeks and foodies, we thus started with simple DIY fermentation experiments. Two interesting aspects of the fermentation process we thought we should explore within the Singaporean climate are the effects of the ferment's exposure to different temperatures, and the availability of local ingredients.

During our first experiment with yogurt fermentation, we ran a tasting evaluation, trying to figure out the effects of different types of milk and starter cultures used (Figure 1). We observed that different types of organic and non-organic milk deliver diverse taste and texture. We wanted to try also the unpasteurized pasture-fed cow milk that is usually recommended in fermentation literature; however, we soon realized that in Singapore it is almost impossible to get it (which is a common problem in many parts of the world where hygienic standards prioritize safety over taste). Getting access to the proper local food resources was confirmed as one of the issues to be resolved within the local GutHub community.

Our second trial was vegetable pickling (Figure 2), where we tried different approaches, such as going completely 'wild' and ferment without salt or starter of any kind, or probe different salts and concentrations. We also tried to expose the mason jars to different temperatures (room temperature, air-conditioned room, balcony, and oven with a light bulb). That brought some significant taste variations and proved that the tropical climate is ideal for the fermentation process.

We have also considered the particularities of local socio-political context and the advantages as well difficulties that are likely to arise along DIY food experiments (Figure 3). Singapore has a rich variety of shopping malls and supermarkets, as well as a dense and fast broadband network, but also a great lack of locally grown food. Being listed among the top countries with the highest Internet connection

Figure 1. The yogurt tasting session

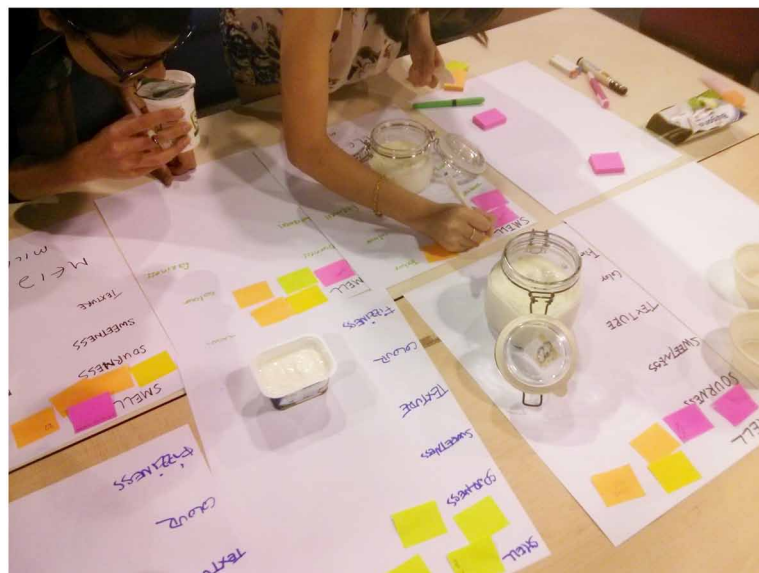
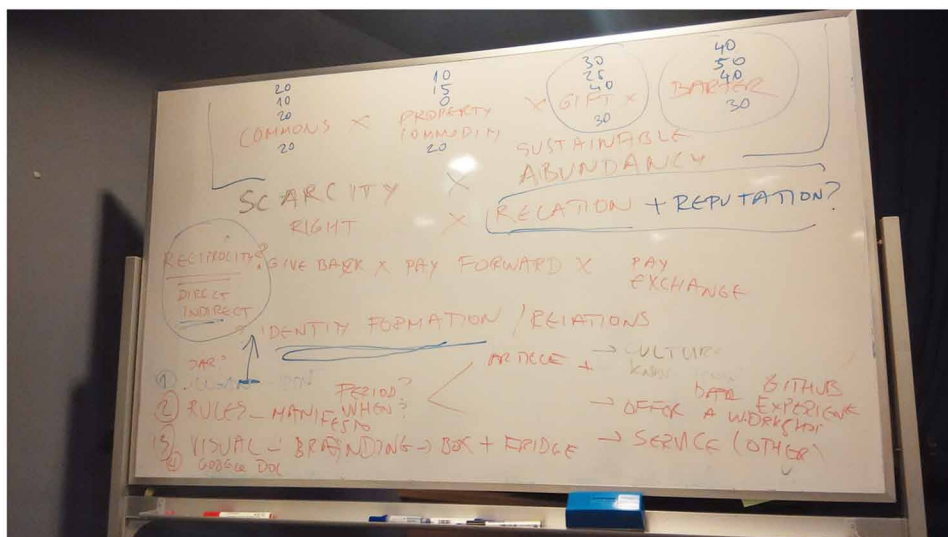


Figure 2. Not only the starters but also the jars with ferments can get their nicknames



speed and mobile phones penetration (We are Social, 2015), Singapore surely does provide an efficient infrastructure for technology-enabled citizen interactions and IoT experiments. This efficiency also applies in the field of food production that is based mostly on a cost-wise import. However, there have been a growing number of emerging locavore initiatives (e.g. Edible Gardens Singapore, 2015; Open Farm Community, 2015; Urban Farmers community, 2015), and Singapore thus seems to provide a good context to probe technologically enhanced DIY food practices such as the ‘smart’ home fermentation.

Figure 3. First sketches of the GutHub project were similarly messy as fermented mason jars



That initiated our interest in how to integrate emergent technologies, such as the blockchain or open hardware to support the local fermentation community interactions.

Participant Observation in the Communities of Bread and Kefir Fermentados

Based on the previous literature review, we decided to focus on two types of foods that are popular, but quite challenging to ferment in the Singaporean context. The first was sourdough that is commonly used for a preparation of artisanal homemade bread and other pastries. The site where we conducted the observation is a Czech Facebook community “PečemPecen.cz” (PečemPecen.cz, 2013) where “pečem” is a Czech term for baking and “pecen” for a loaf of bread. The reason for choosing this site was its large site traffic and the relevance of posts, and also our familiarity with the Czech language and culture.

The second food chosen was water kefir, which is already quite popular in Singapore. We wanted to explore particularly the Singaporean online communities, as we were interested in finding more about the local ingredients to ferment water kefir successfully. From our first-hand experience with the local grocery shops, we knew that the choices are limited (for example, a well water that is often recommended for water kefir fermentation, is almost impossible to get here).

PečemPecen.cz – Online Heaven for Sourdough Bread Lovers

Sourdough bread is a bread made from fermented dough instead of commonly used baker’s yeast and is said to have tangier flavor as well as better nutrition profile than the mass produced pastries. The sourdough bread starter called “leaven” is usually made of flour and water, with different ratios of both producing different flavors. Although bread is not a traditional staple food in Singapore, we noticed an increased local interest in artisanal homemade breads offered by newly emerging Western-style bakeries.

The PečemPecen.cz community on Facebook had over 21 600 members on the date of the analysis (April 13th, 2015). That is a large number not only for the Czech speaking pages but also for all the Facebook fermentation pages in general (to our knowledge, only the Wild Fermentation group started by Sandor Katz has a larger user membership). A lively discussion on the PečemPecen.cz timeline includes recommendations on the sourdough preparation; troubleshooting; as well as proudly shared pictures of homemade breads. Members are mutually supportive of each other’s fermentation achievements – a picture of a heart shaped bread loaf would generate some 1000+ likes (Figure 4).

An interesting interaction in this community, which we decided to appropriate in the GutHub design, were the regular live leaven-swaps organized in local Czech cafés. The bread lovers would meet, exchange their leavens, and discuss their personal experiences with bread making. The swaps are performed on a non-monetary barter basis, and participants either trade one leaven for another or if they do not have a leaven to share, they ‘pay’ with a cup of coffee. The leaven starters thus seemed to us as a commodity naturally designed for a barter-like P2P transactions. This successful model of barter food sharing encouraged us to initiate the regular GutHub meet-ups and open the Fermentation Bank of starter cultures.

Singaporean Tales of Precious Water Kefir Grains

Water kefir is a mild zesty fermented beverage that tastes like a light soda. The starter cultures known as water kefir grains resemble semi-transparent crystal gems and are one of the specific starters that are indispensable, and always need to be added to start the fermentation process (Figure 5). Thus, a system

Figure 4. Warm human-microbial relationships: a heart-shaped bread loaf with author's comment "I just love my bread so much, I hope the leaven loves me too:)"
(Adapted from [PečemPecem.cz, 2013])



Figure 5. Water kefir grains



to facilitate a sustainable exchange of these starter cultures is necessary to nurture the local water kefir fermentation efforts. When searching for suitable online sites for the observation, we looked up Facebook pages, various local discussion forums, as well as fermentation weblogs. However, we could not find any single collaborative fermentation group that would offer a continuous and updated discussion about the water kefir fermentation issues.

The first site analyzed was a Facebook page “Kefir, Kombucha & Other Probiotics – Singapore” (2014). It was immediately apparent that it is a commercial page, with the timeline filled mostly with the author’s posts offering starters for purchase. The lack of any discussion about DIY water kefir fermentation or troubleshooting was significant. However, from the frequency of visitors’ posts requesting for water kefir grains, we confirmed that there is an interest among Singaporeans in this fermented product. That made us continue our search for local water kefir related websites.

Eventually, we have found a personal blog with a post titled “Introduction to Water Kefir, Milk Kefir, and How to Make Them” (2014) that offers some more elaborated water kefir discussion. The author provides an overview of water kefir, its health benefits, taste aspects, and preparation tips. Most importantly she also offers her water kefir grains to share (“for free, of course!”), which sparked visitors’ attention and became a leitmotiv of the discussion below the blog post (30 comments in total, as for the date of analysis March 4th, 2015). However, at the bottom of the blog post, there is an update mentioning that the author does not have any grains to share anymore. At the same time, though, she offered the visitors to “sync them up with those who have [the grains]”. This finally seemed to us as a hint of a local peer-sharing network formed around starter culture swaps that we were looking for. However, the blog post stopped short of building a community in a form of an interactive group maintaining a lively continuous discussion.

The unsuccessful search for a stable Singaporean community formed around water kefir confirmed the relevance of our idea to start the GutHub community.

Based on our hands-on fermentation experiences as well as the online research, we finally came up with a list of components to be included in the Fermentation GutHub design proposal. We confirmed the need to:

- Facilitate a way for live exchange of starter cultures
- Provide an online platform for communication amongst the community members
- Encourage active member participation in mutual support and troubleshooting
- Organize regular live community meet-ups with hands-on tutorials

To introduce the GutHub concept and see if there would be enough interest among locals to participate, we organized a first public workshop in the premises of the local food initiative Edible Gardens Singapore.

The First GutHub Hookup

The workshop titled “Fermentation GutHub Project: Supporting Open Source Food Cultures in Singapore” (2015) was held on April 14th and hosted a surprisingly high number of participants (around 40). We brought a variety of homemade fermented refreshments, such as yogurt, labneh (strained yogurt), sourdough pita bread, various pickles, or sauerkraut. We also invited the participants to bring their own fermented goods and were pleasantly surprised to see that there indeed is some enthusiasm around fermented foods. We got some extra samples of pineapple champagne, ginger cider, honey brew, rice

wine, and dosai (a fermented crepe made from rice batter and black lentils). Surrounded by all the jars and bottles, we presented the concept of GutHub – an open source fermentation community of “human-bacteria hookups with no yeasts attached” (Figure 6).

The Fermentation GutHub Manifesto

The Fermentation GutHub is an online – offline platform supporting Singaporean locavore culture and citizen interactions build around peer production and distribution of homemade fermented foods. The idea is to bring together people from diverse backgrounds with an interest in food issues, sustainability, and safety, but also in healthy dieting, DIY gustatory experiments, and speculative design scenarios. GutHub offers a physical community space for discussing and performing the practice of home fermentation, connecting traditional food making with science, and supporting the activities with online communication tools and OSHW gadgets. The platform offers a free access without any membership fees or other duties and promotes a peer collaboration based on reciprocity and peer barter. The requirement for a non-monetary nature of these transactions represents a core point of the GutHub design, which critically reflects the inefficiencies of industrial food production, as well as centralized IoT scenarios conceived by governmental and corporate actors. The main principles of GutHub are summarized in the GutHub manifesto (Figure 7).

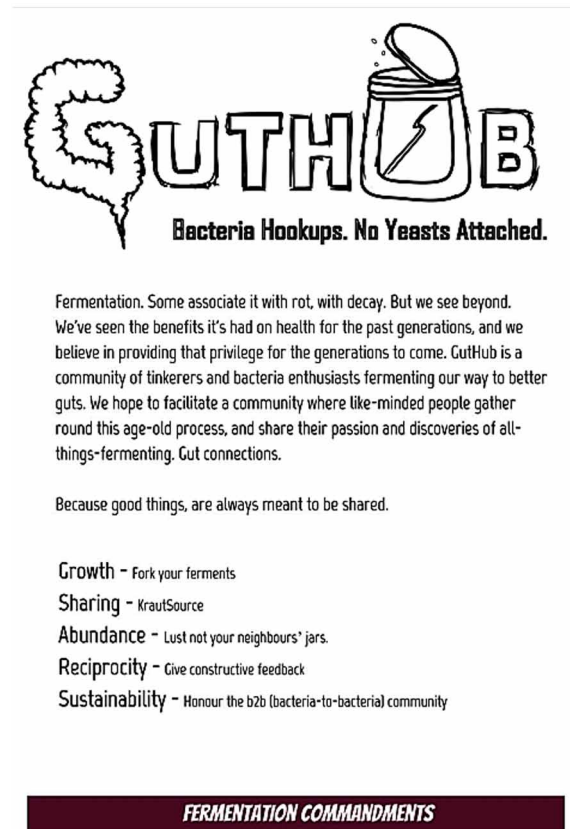
The GutHub platform consists of a “Fermentation Bank” for a storage, preservation and exchange of starter cultures; a “Fermentation GutHub” Facebook group for online troubleshooting and community discussions; a Github repository with fermentation recipes and tutorials; a DIY Incubator for easy maintenance of the starters; and an online “Starter Swarming” map, which lists places where individuals offer free starters to share.

Figure 6. The first GutHub workshop



The Fermentation GutHub Project and the Internet of Microbes

Figure 7. The GutHub manifesto and commandments



Fermentation Bank: A Public Microbial Blockchain

The open P2P sharing of starters as microbial commodities gifted with superfluosness and abundance represents an off-the-grid model of the cash economy based on decentralized barter. We proposed to use the starters as a semi-living microbial cryptocurrency, something like organic Bitcoin encrypted over the code written by microbes and disseminated by humans. Bitcoin is a form of an open source digital currency operated with no central authority, over a public ledger generated by the users (Brito & Castillo, 2013). Its microbial offspring follows the same logic, and the starters are circulated and exchanged among the GutHub members who form a diffused network of equal intermediaries, collectively governing this grassroots economic system. Follow the example of Bitcoin; we decided to set up a 'microbial ledger' that would ensure a smooth transparent flow of the GutHub starter exchanges. This requirement led us to the idea of opening the world's very first Fermentation Bank of starter cultures situated in a publicly accessible refrigerator (Figure 8).

The fermentation Bank follows a model of a common food bank, in which "a warehouse serves as a single collection and distribution point for food donations" (FoodBank Singapore, 2015). However, our starter cultures exchanges were not conceived to equal a charity or free giveaway, such as that performed by food donation initiatives like Food not Bombs (1980). As we have learned from our observation of the Czech online sourdough community, the exchange of fermentation starters is usually based on par-

Figure 8. Inside view of the Fermentation Bank



ticipants' mutual benefits. Thus, we decided to adopt the strategy of food swaps, which are defined as practices where “members of a community share homemade, homegrown, or foraged foods with each other” (Food Swap Network, 2015). Thereby, we also wanted to encourage prosocial behavior within the GutHub community.

However, during the first workshop, we realized that there are likely to be many ‘fermentation novices,’ coming to visit the Bank without having their own starters. We suggested that visitors who want to withdraw a starter sample without leaving any for exchange should offer any skills, knowledge, hardware, or tools they possess. We highlighted that any goods ranging from food, recipes, mason jars, electronics, or anything else that could be crowdsourced by others is highly welcomed. As one of our members said, the progress of the GutHub community should rely on an “unlimited KrautSourcing” (Figure 9).

Figure 9. Fermentation Bank ground rules

1. Take something, give something
Information, tips, skills, recipes, starter cultures, ferments, pictures, jokes, poems, workshops, etc.
2. Be creative in participating and communicating
Share knowledge, ideas, services, donations, tech support or volunteer.
3. Bacteria and humans play nice
No invasive species, no hateful speech or behaviour will be tolerated.
4. Spread the love
(and bacteria).

GROUND RULES

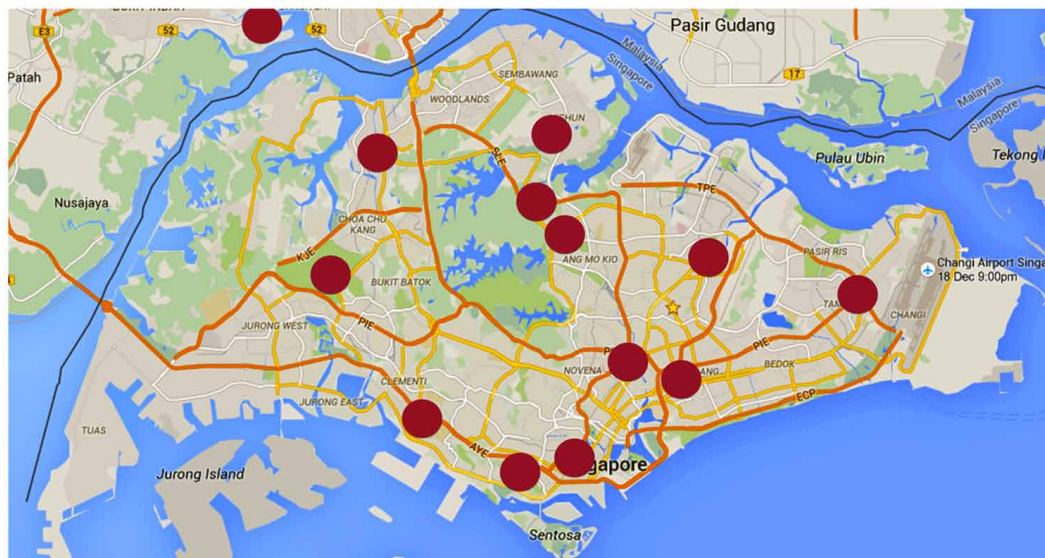
During the initial GutHub workshop, we already received some starters from the participants and placed them inside the Bank, using homebrewed ginger champagne for this festive inauguration. Some of the workshop participants started a discussion about the storage logistics and suggested to consider details such as the ideal jar size, proper labelling, and cataloguing of each deposited starter. We thus proposed to have a “Bacteria Chronicle” with full curriculum vitae of each starter, including descriptors such as its name; attributes (e.g. wild, domesticated, angry, lazy, hungry etc.); similar species (“family tree + siblings”); the country of origin, or type of growth medium and ideal environment (“what it likes to eat and where”). The need to maintain a genealogy and provenance related to starter cultures also inspired us to look more into the blockchain model as a possible convergence for the future.

Online Map of Fermentation Starters: The Microbial Swarming

As an extension of the physical starter swaps performed over the Bank, we proposed to create an online map of locals willing to share their starters (Figure 10). The idea of starter map is inspired by similar projects enabling online collaboration over a map of accessible food resources (e.g. Fallen Fruit, 2004; Mundraub, 2010).

We envisioned that the map exchanges would resemble the system of P2P file sharing via the BitTorrent protocol, which allows for a free distribution of data over the Internet (Cohen, 2008). In the BitTorrent terminology, the network, or “swarm”, enables an exchange among so-called “seeders” (those sharing certain file) and “leechers” (those downloading that file). In accord with the BitTorrent terminology, the GutHub swarm of starter swappers consists of seeders who offer a starter for sharing and leechers who want a starter and are willing to meet some seeder and get it. Leechers might have an adverse effect on the swarming ecosystem, by having a poor share ratio and downloading much more than they upload. As for the Fermentation Bank, we aim to solve this ‘freeloader’ issue with the requirement of reciprocity; however, in the case of the online starter swaps, we left the control of the exchanges to the

Figure 10. A simple sketch of the Starters Swarming map



GutHub swarm itself. While deliberately abstaining from any control, we wanted to test how would these microbial torrents work without any centralization. One issue we needed to take care of, though, is the personal security of seeders. To protect seeders privacy, we proposed that no exact addresses, only the approximate locations should be listed on the map. Each seeder should leave some contact, and the details of the face-to-face exchange should then be set via a private communication.

For now, the map contains only around 20 entries made mostly by the core GutHub members, and the personal fears of encounters with strangers seem to be limiting. Another barrier for people to use the map seems to be the requirement for at least basic technological skills. Although the map runs on a Google map platform, which offers relatively easy navigation, some members have reported a lack of confidence to log in and list their entries. This limitation confirms the digital divide issues that are symptomatic for the majority of social innovation projects involving a use of ICTs. Thus, we need to discuss possible ways how to mitigate these limitations and increase the number of the map entries

GutHub Facebook Group: Online Troubleshooting

To support troubleshooting and mutual help with diverse fermentation issues within the community, we opened the “Fermentation GutHub” group on Facebook that has 187 members to date (March 19th, 2016). Our research of the PečemPecen.cz community has shown that Facebook can serve as a useful channel to support troubleshooting and interaction in fermentation communities. Furthermore, considering the high Facebook penetration rate in Singapore (We are Social, 2015), a Facebook group seemed as a convenient communication channel for the GutHub purposes. So far, the group has served as space for diverse GutHub-related discussions: The group timeline is regularly filled with users’ request for help; pictures from their at-home fermentation experiments; as well as with tips on where to get various starters. We even managed to (finally!) start a discussion thread on water kefir grains swaps (Figure 11).

The group members are supportive of each other’s fermentation efforts - a user post from 8th June is even asking for a starter babysitting (the author eventually received a positive response and her kombucha scobys indeed found their babysitter) (Figure 12).

Figure 11. Water kefir grains swaps finally entering the Singaporean fermentation networks

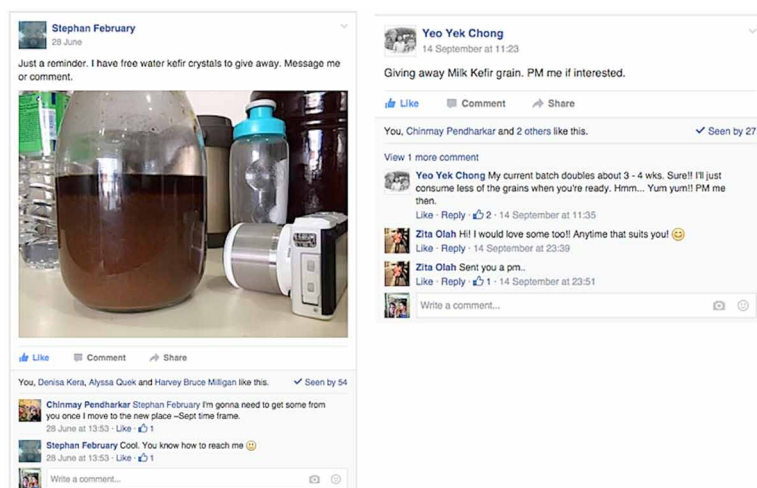


Figure 12. A request for starter culture babysitting solved on a basis of P2P help



Facebook proved to be a useful platform for quick troubleshooting; however, we realized it is not a convenient interface for the exchange of full recipes and lengthy how-to descriptions. We first tried to redirect these longer and more detailed posts into a shared Google document, but neither that seemed to be an optimal option, as it required an annoying scrolling through rather long linear documents. Eventually, we suggested to open a GitHub account on the Github platform to enable for easy sharing, editing and streamlining of the fermentation ‘source codes’.

The GutHub Github: Fermentation Forking

Github is a web-based hosting service for software development and open source code sharing (GitHub, 2015). We were inspired by existing Github food-related projects, such as these created by the community of DIY soylent dieters (Genetic Soylent, 2013; Soylent Solver, 2014), or more conventional GitHub cookbooks (e.g. Fork the Cookbook, 2015). Following the Github ethos of open source code sharing and tweaking, or so-called “forking”, the online GitHub platform contains fermentation recipes, ideas, and tutorials that can be easily iterated and co-developed by the community members. This forking strategy enables for faster and easier correction of the source code of uploaded content and accelerates the troubleshooting process by letting the users collaborate without time, space, cost or license limits. The idea behind the GutHub forking is that no recipe is ever complete, as there is an infinite number of culturally or otherwise conditioned approaches towards the fermentation. Thus, we hope that this form of peer-developed recipe scrapbook would contribute to the overall diversity of existing fermentation practices.

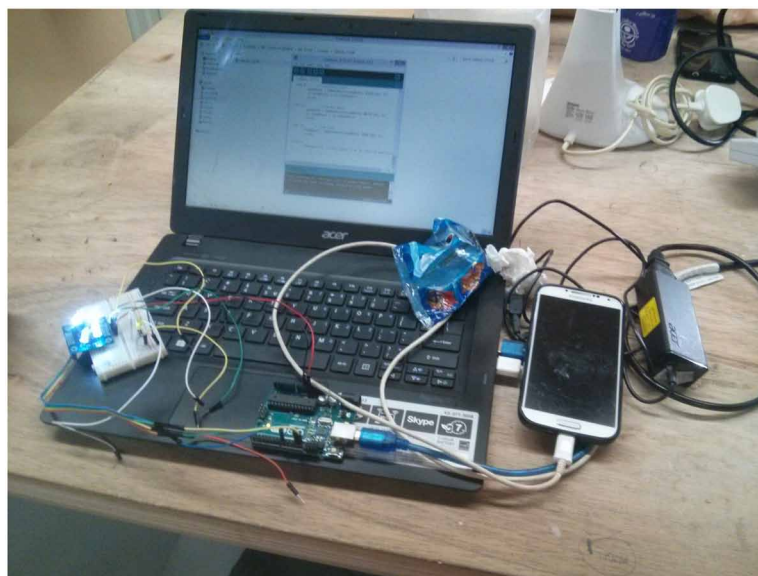
Mother 0.1: A DIY Fermentation Incubator

The last technological feature of the GutHub design is the DIY incubator that we have built with the help of more tech-savvy GutHub community members. Incubators are commonly used for artificial growth of microbiological cultures while maintaining the optimal temperature and other conditions such as the humidity and oxygen inside. However, the role of the incubator in the GutHub context was to give more confidence to people trying fermentation for the first time rather than to standardize the fermentation process. The GutHub incubator uses DIY methods and components, and consists of Styrofoam box and open source heat and light sensors (Figure 13). The idea is that the heat sensor can detect the temperature in the Styrofoam box and either switch on or off the heat lamp, such that the temperature will stay within a set range of degrees. We also built a relay module to ensure that the heat lamp can be controlled using the sensor and Arduino (Figure 14). Besides the sensors and the relay, we also designed a sketch for a pH sensor using microfluidics device with a cabbage juice monitored by color sensor, which would catch the reaction of the cabbage juice to elevated pH levels (it changes its colors to blue). As for now, the “Mother 0.1” incubator prototype (named after the Mother computer of the Nostromo ship in Ridley Scott’s Alien series) is still under a construction, and we are tinkering with the optimization of the heat sensors. We also plan to include motion sensors for easy remote-controlled ferment stirring and hope to upgrade for the “Mother 1.1” soon.

Figure 13. The low-budget incubator uses a simple Styrofoam box as a container



Figure 14. “Mother 0.1” uses Arduino to control heat and light



FUTURE DIRECTIONS AND CONCLUSION

Smart Networks of Microbes, Sensors, and Humans Extending the IoT Scenarios

The GutHub community is still gaining new members, and the meet-ups are organised on a monthly basis in the Hackerspace.sg, where we maintain the Fermentation Bank. In the future, we plan to continue observing the encounters around the Bank as well as the forking activities on our GitHub platform. Aside from the activities performed inside the community, we also attend occasional public workshops as guest speakers, spreading the open source ethos of human-microbial interactions around the city-state. Along with these activities, we hope to attract more locals and involve them in open discussions on the issues of sustainable food production, as well as IoT utopia and future smart city scenarios.

With the GutHub project we also attempted to design a model of sharing economy for Singapore's budding fermentation community, following the objective to provide a platform for easier means of starter culture swapping and hence a better community bonding. The GutHub design tests the idea of a different type of smart city, which encourages grassroots citizens' participation in the sustainable food movement in Singapore. Our experience with the community meetups and DIY fermentation tools shows a model for alternative scenarios around future cities. This model uses symbiosis with non-human actors and hypeobjects across various scales as a base for complex interactions important in IoT. Instead of claiming easy and well-organized decision-making based on data generated by sensors and technology managed by few big stakeholders, the GutHub project shows the importance of grassroots engagements based on low-tech accessible tools.

The GutHub experiment extends the scope of IoT scenarios with microbial semi-living organisms as important actors in the design speculations about the possible urban futures. We propose that these futures should be defined as hybrid and experimental, rather than safe and managed with minimized

risks. The fermentation communities around the world, as well as in Singapore, show that grassroots citizen initiatives can share the benefits of various technologies and use them to mitigate these risks. We believe that this form of technologically supported relations between humans and non-humans can positively improve the urban production of food, as well as community interactions and civic engagement in designing of more resilient cities of the future.

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Chapter 3

Assembly, Space, and Things: Urban Food Genome, Urban Interaction, and Bike Share

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ABSTRACT

Each day as one notices more people walking along sidewalks, head down peering into smart phones, the fear is that social interaction in public space is dead. However, the integration of human and non-human processes may connect our communities now in more ways than ever before. New urban design theory suggests that “the city” may not be understood as a whole, rather as an assembly of dynamic urban processes. At many bike share systems around the world only static maps with limited interaction experience. Urban interaction design and the Internet of Things, is changing this experience. The interdisciplinary methodology describes a symbiosis of people, space and things. The significance is the integrated urban interaction design process of: urban design theory using classification of urban experience; geospatial analysis at the street-scale of point addresses, and fabrication of a test-bed kiosk to test ambient sensors and user interaction. Connectivity experienced in the virtual space of social media may now enter back into the physical realm of public space.

INTRODUCTION

At a time when people are seen walking on city sidewalks intermittent with their heads down looking at smartphones, one might think that social interaction and community connectivity in public space are dead. However, the integration of human and non-human processes may enrich the social experience of urban space now more than ever. New food options and temporary street festivals are randomly found walking or driving. But this is uncommon. It is far more common to find distinctive new food options from entrepreneurs at restaurants using Yelp or mobile food trucks using Twitter. Through new

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collaborative understandings of urban life as an assembly of processes, open geospatial information systems and interactive design technology, is the emergence of urban interaction. People may now be connected in the city through nuanced details of their personalized interest. Specifically, the opportunity exists to transform the current limited third-generation bike-share station kiosks into interactive street portals through personalized user decisions. The introduction of crowdsourcing applications such as Yelp, Twitter, Pandora and Facebook allow people in cities to connect through decisions of their urban experience. With bike share systems in 700 cities in fifty countries worldwide, nearly doubling in the last three years (Urban Planning, 2015), research into new interactive bike share kiosks may show how urban assembly, space and things meet.

Urban interaction design, as described in the interdisciplinary work outlined here, requires an assembly of knowledge greater than a collection of the three individual research parts of urban design theory, geospatial information systems and kiosk interaction design. The broad complexity of the overall investigation confronted the deeply focused work within each expertise. At times any isolated area might push far away from the broader intended purpose to create an integrated urban interaction experience for urban dwellers, or from the expertise of other members of the design team. Yet the iterative workflows (Woodbury, 2010) and the movement of team members from their own expertise to the support of other's expertise helped inform and educate each member and thusly stitch together an overall design process. The integrated research described here falls within a broader scope of current 'urban computing' researcher (Carlo Ratti MIT Senseable Cities Lab - Copenhagen Wheel, 2011) (Frog Design NYC Kiosk, 2013) (Oliver Obrien, CASA Barlett Real-Time Bike Share Website, 2010) who face similar challenges. The urban theory and bike share kiosk system work described here intends to contribute to understand how urban interaction design collaboration operates, its challenges and opportunities. This work is also intended to contribute to the specific investigation of how an Internet of Things may be used to go beyond bike share route planning and to deeply enhance bottom-up and resilient, sustainable community connectivity in the urban processes of today of human and non-human interaction that is only now beginning to be understood.

The first part of the work conceptualized a theoretical comprehensive taxonomy of urban experience called the Urban Genome. For the purposes of this phase of the research a subset of food or dining experience was then chosen to collect data and will be referred to as the Food Genome. Various dining experience qualities were chosen and ten measurable indicators were used for analysis and visualization in a parametric geospatial information system, GIS. Over fifty businesses were visited in-person to measure the quality, cost and operating hours of food establishments in the study area of downtown Eugene, Oregon. A major part of this chapter will focus on how these qualities of food experience might be used to organize how people of similar user profiles would be informed via five bike stations in downtown Eugene. The last part of this chapter will describe ongoing research about the interactive experience at the physical 'thing' of the kiosk including ambient sensors, differences of public and private interaction, and testing of implicit and explicit interaction. The parallel urban theory, GIS and interaction design research of the team allowed a cross-informed workflow between work efforts.

CONTEXTUALIZATION AND THEORETICAL PERSPECTIVE: AN INTEGRATED APPROACH TO URBAN INTERACTION

The work presented here utilizes a theory of dynamic urban systems. New geographic information system, GIS, tools measure the urban experience of place at the very small urban scale of data points at each street-level building address and may be combined with changing ambient conditions of the environment or users. For example, most bike share kiosks today, including Barcelona, Berlin, New York and Washington, provide only fixed maps of the city. Meanwhile websites such as Bike Share Maps (O'Brien, 2010) use widely available API data showing the real-time use of each station, full or empty, across the last twenty-four hours. The prior represents the fixed city. The later represents live 'urban processes (Harvey, 1985).' We propose that a third-generation bike share system with unique user check-in could provide dynamic information not only about safe routes but far more culturally interactive urban phenomena such as cultural events, local services as well as ambient weather conditions. Users could be connected by the decisions they make, the feedback they provide and the subsequent suggests made to like users – similar to a crowdsourced music listening services such as Pandora (Glaser et al, 2000) and use of the Music Genome Project (Glaser et al, 1999). Such as solution would contribute to the social sustainability of cultural values between community members and make communities more resilient against external forces. It is the motivation of this research to better understand how urban interaction research integrating urban theory of dynamic urban systems, open socio-computational GIS workflows and remote sensing may enrich urban connectivity between people in public space.

Urban Design Theory

Socio-computational workflow that measures dynamic urban phenomena of people and more fixed understandings of the cities requires a challenging integrated approach between current urban theory and the new digital means by which people and computation merge. For example, dynamic flows of mobile food trucks in New York City with distinctively new and changing menus are located by patrons using social media application such as Yelp (Franck and Speranza, 2015). Philosopher and sociologist of science Bruno Latour suggests design approaches that 'attach' (2008) people to the live forces and flows of the city, rather than relying on fixed urban form that, once built, is dated and petrified to adaptive urban flows.

Urban approaches that are temporal and adaptive have gained wide recognition today. Within this area is the appropriation of space by citizens including ideas such as loose space (Franck and Stevens, 2007) and guerilla urbanism (Hou, 2010). Meanwhile computational workflows rely on multiple platforms, bridging in-person interviews using various mobile sensors with dynamic geospatial visualization of such qualitative sociological areas including business, cultural background and architectural infrastructure (Speranza and Maher, 2015). Others computational workflow in urbanism has pointed to more control of local dynamic information flows (Veberes, 2009) and the agency of information in urban design (Gerber, 2014). The key ideas is that urban design is no longer thought of as fixed infrastructure such as traditional notions of uses, transit and open space alone, but rather the urban processes unlike the physical city (Heathcott, 2015), requires an understanding of complex interconnectivity of layers of systems of the city, urban ecologies (Mostafavi, 2010), and time-based information available via interactive design.

Space

Recent geospatial design research to measure urban phenomena may be seen in mainstream tools such as Yik Yak's (Droll, 2013) pseudo-anonymously threads within a 5-mile radii, Uber's (Kalanick and Camp, 2009) spatial networking approach, Walkscore's (Kocher and Lerner, 2007), in overall scoring, its ten criteria and new mapping interface and Zillow's (Barton, 2005) integration of various real estate criteria. More academic geospatial research relies on focused cultural value. Marichela Sepe's PRIN - Project of Relevant Italian National Interest for Pompeii (2013), PlaceMaker tool (2005) and the Div@ter - Dynamic (2014) and interactive platform for the complex-sensitive management of the qualitative data of a territory are recent tools to dynamically visualize walking experience by tourists from a new GIS methodology. Transit oriented research is also investigating dynamic objectives of GIS in planning (Carmona, 2009) and software development and geography (O'Brien, 2010). In fact, Jane Jacob in the *The Economy of Cities* (1969) refers to a theory of 'import replacement' that describes how cities replace the unique goods brought in from other cities, thusly describing the value of unique or diverse production locally within a place. Differences of small-scaled data creation and visualization of on-site and off-site urban phenomena (Speranza, 2014), and ideas of systematic, open and custom formulation of parametric GIS workflows (Speranza, 2015) contributed to the methodology presented here. Meanwhile there is a growing understanding among researchers to include small-scale stakeholders, namely the community and individual residents to act upon, direct or otherwise inform these growing information systems (Bowerman, 2000) from the bottom up (Greenfield, 2010). Including the small-scale and time-based local in urban design is now possible.

Meanwhile, important approaches to visualization in urban ecology (Holzman & Cantrell, 2014) extend the richness of geospatial information found in existing simulation tools by researchers such as Barcelona's Agency of Ecological Urbanism. The visual programming research of Manuel Lima (2011) provided critical examples to research presented here to both organize information in a single understanding but, in the same visualization, allow the viewer to separately understand multiple hierarchies of information. Elsewhere, geospatial business analytics platforms continue to emerge as add-ons to social networking tools allowing businesses to compete for popularity. Data variables are often restricted to purely quantitative existing data rather than more dynamic visual geospatial phenomenological data, ultimately leading to visualization methodology that provides modest spatial insights for individual business owners and falls short of generating actionable knowledge. Demand for spatially sensitive business analytics has pushed large industry players such as Oracle, Microsoft, Terradata, IBM and others to develop services and social geospatial analytics visualization platforms (IBM, 2015) (Lavrov, 2015). to allow both industry players and governmental agencies to begin to transform spatially sensitive business data into valuable insight but these visualizations predominantly stem from a top-down master planning approach aimed at optimizing the city as a system. Only recent innovations in the Internet of Things (IoT) and sensors from small teams of researcher have begun to make clear the possibilities of geospatial analysis using the Internet of Things.

Things

Wireless and pervasive networks have come to support the intersection of space, objects, and users. With an ever expanding growth of network connectivity, the relationship between people, place, and thing will continue to breed new possibilities in the urban environment. The Internet of Things (IoT)

and to a larger extent, ubiquitous computing, will allow users to leverage a range of interaction methods from instrumental engagement (Greenfield, 2006) to more ambient and adaptive means (Mostefaoui, Maamar, & Giaglis, 2008). Ambient in the context of this research refers to both the environmentally relevant data (temperature, light, etc.) as well as a computing interface systems that are contextual aware and predictive (Vasilakos & Pedrycz, 2006) based on the utilization of various sensor hardware. The integration of IoT with bicycle systems technology, namely sensors, user data and ambient data, has only recently been a place of research innovation. First generation free “White Bicycles” began in Amsterdam in 1965. Second-generation bike share “Bycykler København” in Copenhagen utilized coin deposits and locking stations. Not until information technology supported card check-in system in 1998 in Rennes, France, did bike share expand dramatically, especially in the mid-2000s (Sache, 2011). While second generation bike share systems were coin accessed with dedicated locking locations (Colin, 2013). Previously mentioned systems in New York City, Washington, Barcelona, Berlin are third-generation systems introducing digital check-in service, and the DB Berlin system possibly considered a fourth-generation system using GPS and more sophisticated computing to locate and remotely login and unlock bikes without using a station. Other fourth-generation features include real-time data about bike usage of lights, dynamo, brakes and location. Third and fourth generation systems use check-in systems that recognize unique users, important to the use of bike share as a platform for urban interaction research. Interaction design and opportunities to connect community members is made effective both through the visible screen interface seeing the spatial locations of urban experiences but also through the possible suggestions made via audio input and the crowd sourced suggestions made for similar system users.

Various academic investigations provide parallel research to the work shared in this chapter. “Citi Bike Ride” (Nussbaum, 2014) is a design storyboard from the School of Visual Arts includes advanced mobile application interface for way finding and fare recharging. “Bike Sharing Visualizer” (2015) is similar to the “Bike Share Map” of UCL but by an interaction design student and focuses on bike availability at stations but focuses on difference user interface with the stations map. “OPENbike” (Ljungblad, 2014) is a theoretical interaction student design where user personas provide important design criteria for mobile interface the bike design but is not yet implemented into a working bike-share system. These three projects seem to work isolated in design ideation, interface design and bike assembly. No single design is able to deeply replicate the complex urban design, computation and interaction design of a bike share system. While the researchers of the work presented here attempted to collaborate with the Portland Bureau of Transportation in 2014 for a forthcoming bike share system, the city’s preliminary agreement with a system vendor prohibited significant access to the information of the system. The system was effectively closed and proprietary by Alta and Bixi, and data would not be made accessible to the city or its partners even as anonymous information.

The most advanced complete smart biking system at the time of this chapter is not a public bike share system. “The Copenhagen Wheel” (2013), developed in part by MIT SENSEable Cities Lab director Carlo Ratti, like other projects of their lab, integrates expertise in computation, urbanism and interaction design. The Copenhagen Wheel is a wheel for a private bicycle that provides smart kinetic power assistance, regenerative braking, smart controls, an open developer interface and a mobile application interface. The smart design focuses on the individual experience of the user both in physical use and information interface. While a collective interface between users might be possible, the networking of crowd sourced user behaviors and their feedback as a form of community connectivity did not seem to be the design intent of this project. Still this project provided a valuable understanding of the possibilities of smart sensors and user information feedback.

The key research questions for this chapter pertain to the integrated approach of urban interaction design. How can experts in urban design, computation and interaction design collaborate? How can an integrated solution be achieved through a parallel and interconnected design methodology? How can community connectivity, and thusly more socially sustainable urbanism at the scale of human interaction both physical and virtual, be supported by integrated urban interaction? How can bike share serve as an effective platform to test the real-world limits and challenges of physical interaction design and the consequences of human, environmental and computational processes?

METHODOLOGY: INFORMED PARTS OF A WHOLE

Urban Assembly and Classification

Urban theory today has shifted from the measurement of fixed form to the measurement of temporal phenomena. The way we measure the urban environment is becoming increasingly framed in the social context as well as fixed forms. The same way we previously thought of transit as the primary infrastructure that connected our communities, we may now consider information as a similar medium that defines the way we experience urban life, both individually and as interconnected communities. Taro, a Japanese sushi restaurant owner in Eugene's hippy Whiteaker neighborhood adds to the diverse cultural understanding of one's urban experience in Eugene, Oregon. Similarly distinctive small and medium-sized urban experiences play a role in the way we understand our experience at the scale of cities, districts, neighborhoods or individual streets including the Whiteaker in Eugene, Oregon. While databases such as Google provide some of this existing data, new methods of data collection and sensors within the Internet of Things, make this new infrastructure open to urban interaction designers and potentially accessibly as real-time data flows for everyday users. "The urban" is now seen as an assembly of processes (De Landa, 2006) and made possible by the Internet of Things. The interconnected whole of the various systems and urban processes of cities is greater than its collective parts, and in fact questions if understanding the city as a whole is even possible (Heathcott, 2015).

Urban ecology describes a new way of seeing cities as dynamic organisms of integrated systems (Mostafavi, 2010). Urban design is no longer seen as fixed infrastructures of land use, transit and public open space alone. Cities and even neighborhoods compete for new livability, walkability and startup indexes that vary from traditional metrics of income per capita and cost of living. Urban ecological models try to simulate this interconnected system of urban conditions. Urban simulators such as those found in Salvador Rueda's Barcelona Agency of Urban Ecology measure a neighborhoods' access to social diversity from: 1) land use, 2) demographics and 3) transit infrastructure (Rueda et al, 2012). Meanwhile MIT's SENSEable Cities Lab uses projects to understand data access (Nabian et al, 2013) using ubiquitous access of mobile computing to sense the city. Computation in design and in everyday use in the Internet of Things, now provides new understandings of how cities and urban experiences are interconnected.

Urban Genome and Food Genome

A classification system of urban experiences was developed much in the same way Pandora's (Glaser, Kraft and Westergren, 2000) Music Genome Project (Glaser et al, 1999) serves as taxonomy to classify

various music experiences for user personas. For research presented here a comprehensive urban experience framework was conceived and is currently in development, called The Urban Genome. Qualities of The Urban Genome cross disciplines of urbanism, transit, ecology, sociology, physiology and computation. Theoretical formulation of The Urban Genome began with a variety of ideas from urban design theorists (Jacobs, 1969) (Franck and Stevens, 2007) (Gehl, 2010) (Allen, 1999) (Rueda, 2012). A subset of urban experiences from The Urban Genome related to dining experience, called The Food Genome, was utilized for this study. By referring to this subset as the Food Genome, it should not be confused with other research initiatives that focus on the isolation of unique identifiers of food data related to calories, consumption, and brand variations (Jalonich, 2013). This particular term was an outgrowth of the larger The Urban Genome framework and came to focus specifically on dining indicators coupled with spatially relevant data. Likewise The Urban Genome named here was not conceived with the awareness of geographer Jonathan Fink's "The Case for an Urban Genome Project," that is a call for a broadly interdisciplinary consortium of experts to map the DNA of urban space (2011). While the design ideation would utilize the unique user check-in registration of third-generation bike share system to support community connectivity through user route suggestions and feedback, the design would not preclude other means of unique registration. Likewise the design would use the interaction opportunity at check-in of the stations, and it would not preclude other means of interaction with bike share use such as via mobile smartphone apps, voice recognition audio input via a headset or haptic interaction on the bike.

Ten criteria were chosen to inform The Food Genome including location, cost of meal, origin of owner, food menu genre, hours, customer type, cleanliness/experience, indoor/outdoor, noise level, quality of food, origin of food, number of customers, area and visibility to food preparation (Figure 1). Three of these indicators were then chosen to represent a broad test set of indicators for data collection and somewhat mirroring the effective criteria of Yelp but with data gathered by the researchers on-site, namely 1) the quality of spiciness, 2) the sociological indicator of cost access and 3) time-based understanding of open hours of operation. These three indicators would be combined with geospatial data of user locations and potential arrivals at five various downtown locations. An interest was also made to consider ambient light and weather phenomena in the suggested locations of bike share users. These

Figure 1. The food genome; indicators for on-site measurement



test criteria would be used for specific user types to suggest appropriate dining options and closest bike share stations to secure bikes and then walk on foot. This classification system and inclusion of ambient conditions would provide a way to organize dining options and match them to users. An eventual mechanism would be used to allow possible new criteria to identify users. Feedback from users either at the station, bike, mobile application interface or home computer would allow user personas to evolve and provide similar recommendations to like users. The suggestions would be used to select destination but also identify the closest bike share station and walking route as a route of urban experience.

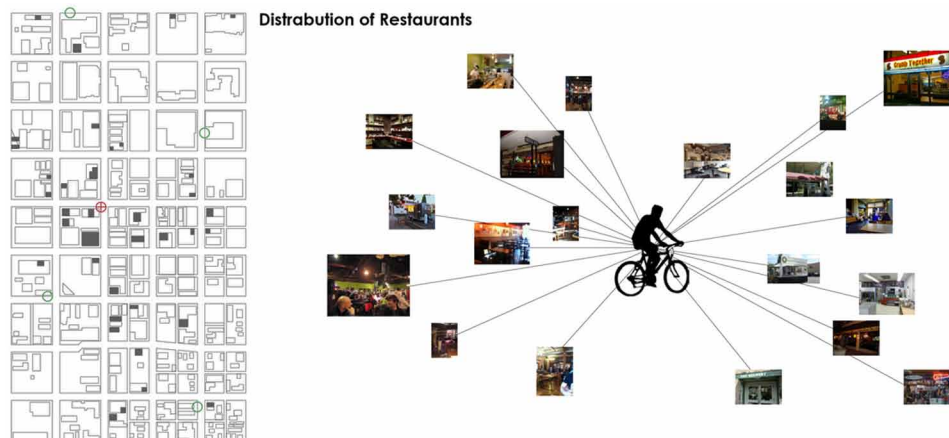
Open GIS: Data Collection, Analysis and Visualization

Urban experience is no longer an autonomously human process. The feedback and behavioral information mentioned above allows information for each urban user to be part of a smart system. Traffic apps, transit apps and Facebook events connect people. While we may understand the use of Google maps for efficient navigation from point A to point B, the expanded infiltration of digital networking and the Internet of Things has far broader implications in our everyday decision making, subsequent urban interaction, and an ability to bring people together in space of like and spontaneously unlike interests. The foods we choose to eat, where they are located and the people with whom we interact are now deeply affected by non-human infrastructure. Information informed spatial understanding is a new norm (Figure 2).

Data Collection and Open GIS Methods ‘Data from Scratch’

The purpose of the GIS data collection methodology is to measure various designer selected indicators that support experiential qualities of The Food Genome. Rather than relying on the various formats of existing data such as Yelp data, new data from scratch (Nabien et al, 2013) was created to ensure accessibility to work with the data in a custom parametric GIS created in the Rhino Grasshopper (Rutten, 2007) interface using the Elk and Human plugins and custom scripting. Traditional planning GIS such as ESRI ArcGIS software relies on city databases of proprietary “shape files.” Neither the data nor the

Figure 2. Downtown Eugene, Oregon, Food dining options as geospatially located from central bike-share station and choices of qualitative urban experiences for each user



analysis and visualization would be as open as the more mathematical interface of Grasshopper or the geometric visualization options.

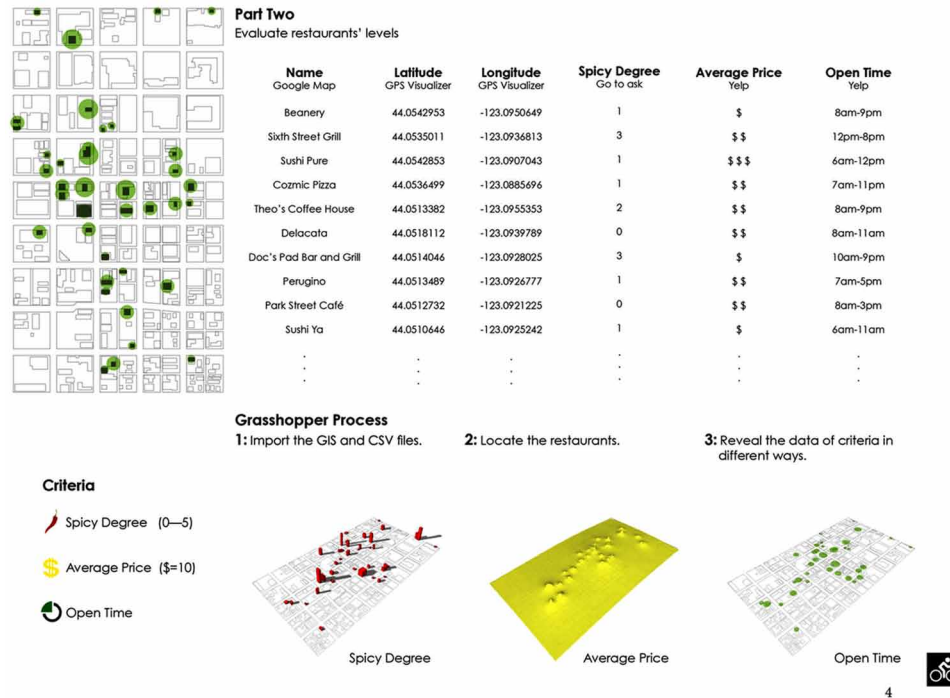
New data was gathered via in-person interviews and on-site data collection at approximately fifty dining experiences including restaurants, food carts and cafes in Eugene, Oregon. A test set of three of the fourteen conceptualized indicators (Figure 1) were chosen. The three indicators included: 1) cost accessibility; 2) time accessibility measured in hours of business; and 3) food quality descriptions done via in-person interviews with shop owners. Additional indicators could be used in the future including shop owner's background based on their place of birth and that of their parents, years in business and origins of recipes, qualities studied for food cart and food truck mobile cuisines options in New York and Portland (Speranza & Maher, 2015). The methodology used in-situ data collection as well as existing information found on-site using a spreadsheet format and brought into the Grasshopper platform via a CSV spreadsheet format. With data points taken at each address the scale of GIS data visualization is smaller than most planning maps. This data complement top-down planning initiatives that have led to fixed urban structure with more comprehensive understandings of bottom-up street-level activities that vary the quality of urban experience within the fixed infrastructure.

The work applied sociological protocols of data and statistical analysis. Data was measured based on numerical and rating systems 1-5. Care was taken in both computation analysis and visualization to avoid information flattening or combining unlike qualities. The workflow including on-site data collection makes possible the ability to assess and capture spatial experience that is otherwise not possible when either data mining, using an existing database or using Google Streetview. The iterative nature of the design process allowed adjustment to the rating and measurement systems upon site visits and returns to the lab. The result is a measurement methodology, though similar to Yelp in some ways, but more open and more accessible of a new scale of GIS information and one which allows custom election of how to measure and compare various parts of an urban ecological condition including social interaction (Figure 3).

Route Planning / Shortest Path / Station Selection Spatial Analysis

The concept for a bike share system of social connectivity is geospatial in various ways. Current bike share systems are often deployed in critical mass with dense station location as close as within three to four blocks along popular routes. Barcelona's *Bicing* system features a fixed map of nearby stations. The map is small. Street names are often not visible. Even if one could remember the map of the location of a station near their destination there is no guarantee that the station would not be full, thusly resulting in the need to use a next proximate station and walk further. All bike share systems are inherently multi modal in this sense that one does not expect to have a station at their destination but one expects to walk to their destination from the nearest station. Similar to full stations is the problem of empty stations, likewise causing one to walk to a nearby station, still not knowing if that station is empty. In both cases of full and empty the lack of information to users means that they are unable to accurately plan a trip and often either buffer in additional time or do not use the system for certain necessary tasks such as business meetings or picking up children from school. Routines certainly inform expectations such as rush hour. And system managers are able to track stations and make adjustments by adding more bikes to a location. Distribution is typical for cities such as Barcelona strong topographic features but redistribution is expensive. Non-periodic events include traffic accidents, road construction, closed streets or

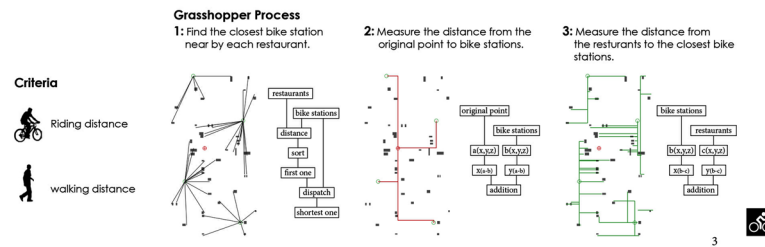
Figure 3. The food genome, Downtown location of food dining experiences, data collection list and parametric Rhino Grasshopper processes



sidewalks, weather conditions and other urban anomaly event. However, the lack of information interface clearly impedes reliability.

The expected multi-modal process of using a bike share and then walking to a destination is expected from all bike share users. In the case of this research to offer recommendations of dining experience using algorithm of The Food Genome route planning would be necessary. Firstly, upon a recommendation of a food experience, ie restaurant or food cart, the service would find the closest bike share station to that final food destination. Grasshopper was used to iteratively locate, measure the distances, sort and select the closest available station. Then Grasshopper was used in a two-step operation to find the most station efficient station to use for that food destination by 1) measuring the distance from the original location point to the bike stations and then 2) measure the distance from the restaurants to the closest bike stations. The two-step process is necessary to account for both modes of each trip- the bike trip and the subsequent walking trip. Users may select between various routes options of walking and biking similar to Google Maps or information on their user behaviors may be stored in their profile and in like profiles to make a suggestion based on expected preferences. With live information about station accessibility and predicted availability (Ray, 2015) the system could provide a more reliable method to do not only quantitative route planning but suggest a qualitative experience (Figure 4).

Figure 4. The food genome, shortest distance for combined ride to station and walking distance analysis

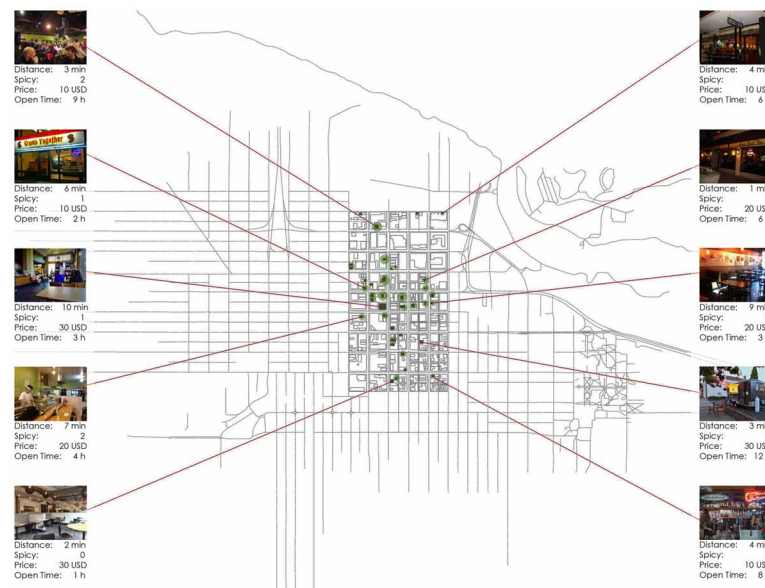


Visualization

Visualization of different types of information, planometric, numerically informational and photographic, has been done in the area of landscape architecture and urbanism including the mapping collages of James Corner in the 1990s. Time information was often included in these images. Likewise this bike share system that makes recommendations for qualitative information such as food dining experience would combine photographic information, distance, spiciness, price and hours of operation with spatial mapping of the city. Typical GIS maps so not include this specific detail. Figure 5 shows a planometric version of this information. Meanwhile Figure 6 begins to show a three-dimensional version of this information, adding the z-axis as an additional axis of information. Following sociological protocols, the importance was not to mix either numerical or visual information types. However, while not combined or flattened, and as with the James Corner diagrams, the spatial relationships of this information are important to the understanding of the knowledge gained by the user.

Understanding of different visual parameters at this scale of urban design greatly enhances the interaction design. One does not have to rely on Google map underlays. Geographic base information such

Figure 5. Visualization of qualitative and quantitative information, plan view



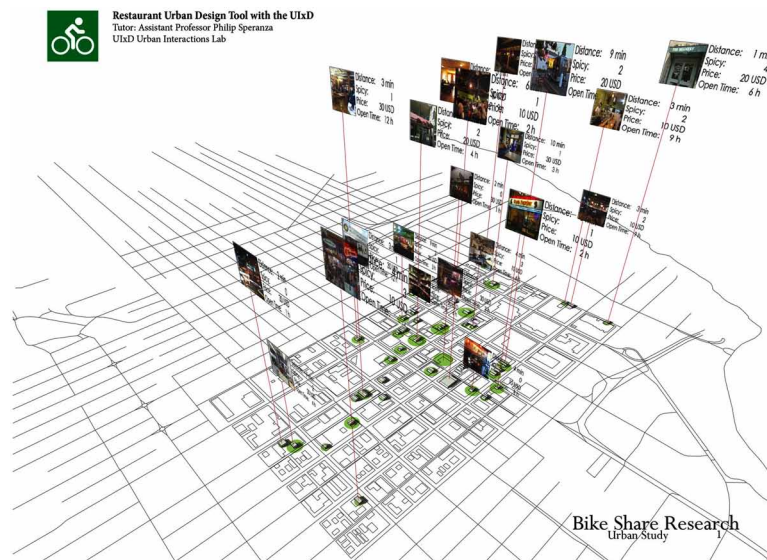
as major and minor streets, highways and bike paths were imported from existing OpenStreetMap files in OSM format and brought into Rhino Grasshopper via the Elk plugin. Building outlines were initially brought in from the OSM database but inaccuracy resulted in adjustments made to the map in Rhino 3D. The alternative use of ArcGIS shape file data would rely on proprietary data of existing origin. Combined with the existing OSM data was custom data brought in via the custom CSV database. Visualizations in plan could then include size and color of circles at dining locations. Vertical line thickness and size of image could also be parametric. The overall height of the photo and numerical information could then represent an overall assessment of the information for each user.

The final visualization thusly provides two forms of information – the granular makeup of data of various types of information and an overall assessment. The user may use the information to make a final decision or they may rely on the overall assessment and or provide user profile information. What is key is the separation of types of information and how to provide that to the user at the station in the form of a kiosk display. Content in our research was self-sourced but in the future could be crowd sourced. Visualization parameters would also be user controlled for their personal user profile or by similar user persona types.

IoT, THE Kiosk as Urban Interaction Portal

Making contextual data accessible and actionable in the built environment was one of the fundamental aims of this research. This type of data has come to represent a new form of urban infrastructure that is often leveraged for large-scale planning and optimization efforts by city administrators and consulting groups (Greenfield, 2013). In this large-scale (macro) approach, municipalities utilize command and control centers to oversee and ultimately optimize the city as a system. Our research sought to capitalize on this increase of data by taking an abstract concept and making it tangible, accessible, and actionable to

Figure 6. Visualization of qualitative and quantitative information, as analyzed for suggestions but visually unflattened for simultaneous overall understanding and individual data comprehension



the average person in an urban environment, allowing individual citizens to contribute to and use this data infrastructure at the small street-level scale of urban interaction. To make this new urban infrastructure visible, a portion of this project was dedicated to providing a situated platform for human street-level interaction. One of the benefits of situated technology versus mobile computing devices is that they become part of the environment as well as provide for a coupling of space and context (McCullough, 2013). These types of platforms have the opportunity to act as a portal or hub of engagement between user(s), communities, and the city as a whole. In particular, these points of interaction aim to have the ability to display dynamic and real-time information about the city including public and private services, locomotion and navigation, as well as emergency notifications. As places, communities, and services are constantly evolving within the urban landscape, existing static street-level displays and wayfinding including maps and notice boards, do not support the dynamic behavioral qualities that describe the urban processes of cities.

A physical test bed kiosk (Figure 7) was built to gain feedback from actual users in exterior street-level environments similar to those found in many public spaces. The test bed also allowed the project to evaluate several of the technical hardware issues that are involved in deploying kiosks in an urban environment. Ultimately this prototype acted as a precursor to any future initiatives around the design and development of a specific bike share kiosk

Public vs. Private Displays

Public displays, billboards, and signage have long been utilized to convey geo-spatial visualizations. Perhaps the most utilized of these is the combination of place and resources resulting in a common location map. These old platforms relied on static and consistent data sources that were periodically updated when major portions of the location or direction had changed. By contrast, digital displays and kiosks provide for a flexible platform that can convey dynamic information at a specific location. Although these types of displays can be used to convey changing situations and cycle information, many of the current incarnations of these displays are for public consumption and provide little direct interaction by individual users. Thus is the challenge in denoting a public display versus private interface. Providing affordances that both supports consumable public information but can also initiate or even invite private

Figure 7. Field assembly and final test bed



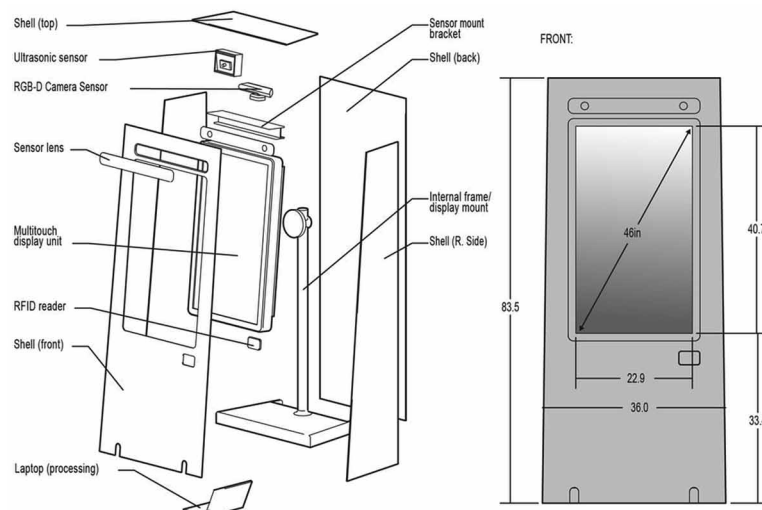
interactions on a single hardware platform remains a challenge. In an effort to address this challenge and leverage two modalities in a public display, our test bed kiosk examined a range of sensing technology aimed at responding to motion and proximity of users around its general vicinity.

Spatial interactions and public displays have been a topic of research for some time. This past research has sought to identify common patterns of movement around public digital displays as a way of prescribing frameworks for future interactions (Michelis and Send, 2009). Although these frameworks have come to define the relationship between users and displays as thresholds (Brignull and Rogers, 2003), zones (Streitz, Rocker, Prante, Stenzel, and van Alphen, 2003), and phases (Vogel and Balakrishnan, 2004); they have yet to sufficiently prescribe an approach to address the constraints that exist on a public street or transit locations. As many of these patterns are directly affected by the very space they reside, we determined that a prototype coupled with preliminary field testing was an effective one way to gain knowledge about the application of a kiosk in a street-level context. The particular aims of the early prototype design and development were examining how various sensing technology could identify certain elements of pedestrian traffic and respond to that by cycling the display from a public message to a private message. By switching messages or modalities based on the direction and movement of individuals and groups of pedestrians, this prototype could better elicit private interactions. In short, the prototype kiosk coupled with sensing capability functioned as an ambient / adaptive interface providing a greeting prompt to passing street traffic.

Sensors: Proximity and Speed

The fabrication of the kiosk test bed (Figure 8) was composed of a 46 inch touchscreen display, internal frame, exterior shell, a laptop for processing, and several sensors. This general configuration would allow for relatively quick deployment to street-level sites for testing while also allowing for flexibility to modify and improve the overall design in the future. Additionally, the exterior shell provided protec-

Figure 8. Configuration and layout of test bed



tion and concealment of the internal components so that pedestrians walking by the device would focus primarily on the touchscreen display.

The greatest challenge in the prototyping process was testing and identifying an appropriate piece of sensing hardware that would capture the movement of pedestrians as they approached the kiosk. Referencing researchers that have done work with touchscreen displays and sensing (Grace, et al., 2013) (Wang, Boring, & Greenbery, 2012) helped to frame out several approaches. The three initial sensor arrays that were prototyped and tested in an indoor application were; passive infrared, RGB-D camera, and ultrasonic rangefinder. While each of these had benefits and drawbacks, the challenge was isolating the active movements of foot traffic through a known movement corridor which was initially defined as a sidewalk. To isolate these movements required the collection of two primary elements; the distance of an individual to the kiosk and the speed of approach. Initial tests utilizing the passive infrared (PIR) sensor proved unproductive as the hardware only produced simply binary signals representing motion and wasn't sufficient enough to help identify an individual pedestrian. The next sensor built out looked at the capabilities of an RGB-D range camera. For the sake of time and resources, we utilized an off the shelf generation 1 Microsoft Kinect mounted at 6.5 feet off the ground. Although this camera has a highly robust level of functionality when it comes to tracking distance and speed as well as isolating individual targets, it failed to perform adequately in exterior environments due to its sensitivity to ambient light. Ultimately the best sensor for the test application was the MaxSonar-EZ1 ultrasonic rangefinder coupled with an Arduino Uno processing board. This configuration allowed for greater flexibility to adjust ranges of sensing as well as the speed of response in cycling between public and private display prompt. Initial field tests have allowed us to fine tune the beam width and better target pedestrian travel in sidewalk applications.

ADVANCING AN INTEGRATED APPROACH TO URBAN INTERACTION

Urban interaction design, like urban design and the current theory of urban ecology, requires a methodology that integrates complex systems of thought, space and things. Visualization and sensors without an understanding of social connectivity and urban experience will lack structure or a theoretical basis of tested conceptual underpinning. Geospatial analysis can work with computer information and interaction design to test user engagement but requires a clear theoretical framework and user input. Theory alone and things alone will not test user experience. The work presented here discusses a three part approach to enhance community connectivity: 1) integrating urban theory using a test subset food genome; 2) Geospatial Information Systems approach at the small-scale of streets and shops; and 3) interaction design at the physical test-bed kiosk to measure human interaction and possible feedback within the system.

At the heart of this part of the research was the development of a classification to associate users. The Food Genome allowed the researchers to collect new data on-site to match them with like users. Like Pandora's Music Genome Project, the Food Genome solved the problem of not have a theoretical underpinning and associated taxonomy to systematically differentiate urban experiences within the subset of food dining experience. The taxonomy was intentionally broad across both quantitative data such as cost and hours of operations but also tests the transformation of qualitative to quantitative information in a workflow of sociological numerical, typological and rating systems.

The geospatial analysis provided not just a scoring system for the system to provide recommendations but solved the problem of cross evaluating multi-modal biking / walking combinations for the closest route. While efficient route planning did not represent the creation of new understanding alone, it was necessary to add the qualitative experience of route length and quality to formulation of food dining experience. The geospatial visualization also allowed affirmations about small-scale patterns of locational information for the test area in downtown Eugene, Oregon including affirmation of many locations along key axis of the central north-south Willamette Street and pedestrian east-west Broadway and Eight Avenue. The data did reveal that higher costs were less centrally located with spicier food associated with ethnic cuisine was located centrally downtown. The data could provide preliminary relationships between food affordability, quality and downtown location. Unlike Yelp and Walkscore, the analytics provide a synthesis between qualitative and quantitative output in the form of suggestions for a broader urban experience rather than siloed data sets that require end user interpretation and analysis.

The primary purpose of the test-bed kiosk is to test user interface and eventually test suggestions and the feedback system. Interface design in public space is different that hand-help mobile computing and the public to private experience benefits from ambient sensing that acknowledging the environment and modes of use by either the distant engagement of many or the individual engage of one. Real-world problems of ambient light interference, sensor direction, orientation of the screen to the direction of approaching pedestrians and bicyclists, and resistance to weather and security issues, were all considered and solved for to collect new user data.

CONTRIBUTIONS AND FUTURE DIRECTIONS

The overall aim of this work was centered on the intersection of people, space and objects coupled with the growth in sensing, pervasive interfaces, and ubiquitous networks. With the evolving opportunities and inflection of new technology in the urban domain there will continue to be a need for new approaches to addressing this emerging problem space. As a result, this chapter proposes that these growing intersections will also lead to continued intersections among disciplinary work. What was once considered architecture or interface design will continue to merge and cross-pollinate in ways that are currently embodied in this work as well as the unforeseen future. This cross-pollination will require new frameworks in urban design theory that support the utilization of geospatial information systems combined with user interface platforms situated in the urban environment. To that end, this research examined the role that a comprehensive taxonomy of urban experience, *The Urban Genome*, coupled with spatial data could be leveraged to better connect a community. To make this framework actionable and accessible to the street-level users, this research utilized a bike share kiosk prototype, *urban interaction portal*. In doing so, the authors also began to examine the potential of these types of interface platforms to not only display information to end users but also to collect localized data through various sensors and GIS platforms. The value in deploying sensors at a kiosk extended beyond data collection but also provided an opportunity to cycle between screen modalities of ‘public’ and ‘private’ thus allowing the portal to respond to passing pedestrians and initiate a greeting protocol.

With these adaptations and continued iterations of the research, cycling through input from disciplinary expertise in urban design, interaction design and computer science, the larger objective of community connectivity may be met. In this way the contribution of the integration of urban interaction design may go beyond bike share planning and support resilient communities. It can now be seen that planning is

not predictive. Floods, earthquakes and hurricanes test our cyclical understanding of nature. Economic and cultural in a neo-liberal world also contribute to unpredicted human conditions that affect the way people are connected. An integrated approach to urban interaction design makes sense. It deeply takes advantage of the ever increasing human and non-human *anthropocene* and confronts the challenges between the real space and digital space that shapes the way we live between people, space and things.

While a theoretical framework, geospatial method and test-bed kiosk were developed in coordination, a fully working integrated system is currently a challenge since access to test the project with a working bike share system has been constrained. While testing was done in Eugene, Oregon, Portland is the closest major city with plans for a bike share system, which delayed, would still require access to proprietary data and platforms by Bixi and or Alta Bike Share. It is possible via Portland Bureau of Transportation to receive limited anonymous data and use a location adjacent to a planned bike share station in Pioneer Square. Ideally a pilot program to test this research in practice in either Portland or Eugene would interface with user feedback in a real system to provide valuable guidance for all three aspects of the classification system, geospatial analysis and kiosk design. In this way the highest level of academic testing necessary to evaluate the integrated workings of the system almost requires the practical application to a working bike share system, to test and inform the effectiveness of either the smaller subset Food Genome or the more comprehensive Urban Genome.

Other more incremental future steps providing effective data gathering and analysis within academic research would be greater inclusion of ambient sensing. Sensors for rain, cloud cover and temperature at the kiosk might offer significant information to make suggestions for route planning as well as direction to cultural and recreational events. Additional real-time sensors in a networked configuration might also base suggestions on conditions at departure stations as well as the destination stations. This would be particularly useful in cities such as San Francisco and Barcelona with significant differences of micro-climate conditions such as temperature because in part of geographical features such as hills, mountains and adjacent bodies of water. Cold weather conditions would also offer valuable insight via future tests.

Lastly, additional user behavioral pattern testing would be useful. A study might try to understand how such a system would affect people's decision making. A user study would inform how suggestions could effectively revise existing theoretical ideas and introduce new indicators, formulation, weighing via existing Social Interaction and Cohesion Tool research and visualization (Speranza, Kiesler and Mai, 2015). A user classifications or persona analysis may also provide valuable insight.

CONCLUSION

The outcome of this research contributes to an enhanced understanding of how the of measure urban experience can affect the way we design virtual and physical connectivity at the scale of cities, neighborhoods and even the small scale of streets. Urban interaction design is enriched through an integrated design process that weaves together understandings of urban assemblies, space and things. Gathering granular, small-scale qualitative data centered on food experience serves as a useful indicator for the larger urban experience that might connect a community through the interactive portal of a bike share kiosk or other urban information interface. This urban interaction design speculation allows those working in the space of urban computing including computer science, urban design, interaction design and sociology, to better shape how the design processes responds to various direct and indirect collaborators – resulting in a symbiosis between smart citizens, IoT and ambient spaces – blurring the agency of people and

things. The contribution of the research methodology described here is intended to highlight moments of intersection and influence between multiple fields. The growth in complexity of urban systems has led to an increasing need to leverage computing and a range of professions to address this complexity. The projects highlighted in this chapter represent the future of overlapping opportunities between urbanism and computation which will ultimately result in the cross pollination of multiple disciplines.

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Chapter 4

Identifying the Temporal Characteristics of Intra-City Movement Using Taxi Geo-Location Data

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ABSTRACT

In this chapter, the authors focus on temporal patterns of urban taxi trips and explore determinant factors in conjunction with geodatabase at aggregate level. Zero-Inflated Negative Binomial model is proposed in light of count data nature and excessive number of O-D pairs with zero trip. Three typical time slots on weekdays, as well as weekends, are introduced as case study to check temporal variations of intra-city movement. The results indicate that trip distance, land use, socioeconomics, and built environment are significant variables that affect the number of taxi trips between two locations. In particular, longer travel and worse economy conditions, such as low employment and average annual income and more population under poverty, may prevent more movements, which have more impacts during peak hours. A better transit system may reduce the taxi trips, except for areas with more subway stations. Developed area for instance more commercial or residential area is more likely to attract more visits by taxis, as well as dense public facilities but with more temporal variations.

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INTRODUCTION

Intra-city movement is short-range, more frequent and random, and with various trip purposes, which is different from inter-city and international movements. It covers all human trips within a city, regardless of transportation modes. This chapter is to study its temporal characteristics and explore external factors (e.g. demographics, socio-economics, land use, and built environment) that influence amounts of intra-city movement among regions within a city. Characterizing intra-city movement needs much trip information that has good spatial and temporal coverage. However, the traditional survey methods, including Revealed Preference survey, Stated Preference survey, travel diary, and national or regional travel survey, are time-consuming and cost-ineffective, considering the large samples required by the problem (Bhat and Srinivasan, 2005; Yao and Morikawa, 2005). Moreover, some recorded information may be inaccurate during these post-event surveys. Fortunately, the emerging large-scale pervasive dataset are with better temporal and spatial information, which provides a new perspective for exploring intra-city movement. Many studies have confirmed the feasibility of using the pervasive datasets in various transportation problems (Asakura and Hato, 2004; Bohte and Maat, 2009; Chen et al., 2010; Stopher et al., 2008; Zheng et al, 2011). For example, in New York City (NYC), approximately 500,000 taxi trips that transport 0.6 million passengers are all automatically recorded by equipped GPS each day. For each trip, information including fares, trip distance, travel time, origin and destination (OD), start time, and end time are recorded in real time. Although number of passengers by taxis is only one tenth of those by transit (New York City Taxi and Limousine Commission, 2014), this emerging dataset has a better spatial and temporal coverage compared with traditional ones, which yields a better understanding of intra-city movement.

In this chapter, to explore temporal variances and causal factors of intra-city movement, one-week of taxi GPS data from NYC are sampled and aggregated at Zip Code Tabulation Area (ZCTA) level. Meanwhile, various attributes of ZCTAs (e.g. distance, demographics, socio-economics, built environment, land use and commuters) are collected as explanatory variables. Econometric models, such as the negative binomial model (NB) and zero-inflated negative binomial model (ZINB), are introduced and compared, considering the nature of trip data, potential overdispersion, and excessive zeros in the dataset. The whole sample is further divided into 6 subsamples to measure temporal variances in intra-city movement. Proposed models are estimated under each subsample. The remaining sections are listed as follows: the second section summarizes background and related studies; the third section presents proposed methodologies; the fourth section shows data preprocessing and variables selection; the fifth section discusses the estimation results and potential applications; and the last section summarizes our works, limitations, and directions for future study.

BACKGROUND

Knowing the characteristics of intra-city movement is very important in understanding complex space-time dynamics during urban study. The interactions between intra-city movement and land use have been discussing for many years. Waddell (2002) introduced a new model system, UrbanSim, to link planning of land use, transportation, and environmental quality. Han et al. (2011) explored human traveling patterns and found human traveling behaviors were strongly affected by the geographical structure. Thus, understanding the relationships between intra-city movement and land use can help us to develop

sustainable urban planning that avoids excessive intra-city movements, reduces traffic congestions, and makes the city more livable. Meanwhile, given urban landscape, researchers can measure intra-city movement in advance and develop appropriate transportation system. Furthermore, the characteristics of intra-city movement are necessary in developing efficient methods in transportation simulation, demand forecasting and traffic control. Kitamura et al. (2000) developed a micro-simulator for trip generation, according to daily activity-travel patterns. Thus, researchers can predict trip generations, attractions, and routes, and then measure traffic conditions dynamically on urban road network. Related authorities can implement some special and efficient countermeasures in advance to cope with potential congestion or other traffic incidents.

The existing studies on the characteristics and causal factors of intra-city movement were mostly based on public transit survey data. Farber, Morang, and Widener (2014) collected transit trips to supermarkets, analyzed temporal variability, and identified the areas and subpopulations with greatest needs for improved mobility. Jia and Harrington (2008) discussed temporal characteristics of Metrorail trips and found increasing social and recreational trips in the evening. Some research papers identified the importance of internal factors (e.g. fares and supply). Castillo-Manzano and Sanchez-Braza (2011) established a flat rate for airport-related taxi services in tourist cities, and found significant increases in taxi demand and driver's average revenues. Bresson et al. (2003; 2004) validated that the public transport demand was quite sensitive to fare changes in England and France. Besides internal factors, external factors (e.g. demographic, socio-economic, and land use) were also discussed. Taylor and Jozefowicz (2012) focused on disabled population mobility and measured the differences in sporting activities. Yoshikawa and Bednarz (2013) validated the differences in travel frequency between genders in Japan. Crotte, Noland, & Graham (2008) verified the positive effects of economic development, i.e. income and vehicle stock, on demand for road traffic in Mexico. Matas (2004) found the positive effects of employment levels on demand for public transport in Madrid. Polat (2012) reviewed the determinants on demand for public transport services and concluded that land use was an important factor. Liu et al. (2012) extracted traffic source-sink areas, which were closely associated with various land use types and intensity. Veloso et al. (2011) explored the spatial and temporal patterns using taxi data and determined the impact of area type. Kim (2011) assessed the mobility and transportation deficiency in an ageing society, and proposed some improvements, e.g. clustering social and commercial service facilities in suburban areas.

While the above studies mainly focused on public transit service, very few studies have examined taxi trips that have more spatial and temporal coverage. Qian and Ukkusuri (2015) identified the significant spatial variance in taxi ridership and the impacts of population, income, road density, subway accessibility, and commercial area. Similar findings are achieved by Yang and Gonzales (2016) through exploring relationships among population, education, income, drop-offs, transit accessibility, employment, and taxi ridership. Besides the spatial variances in taxi ridership, recent years have few discussions on temporal variances. Yang and Gonzales (2014) collected few socioeconomic factors including population, age, education, income, employment, and transit accessibility and explored their impacts on characteristics of hourly taxi ridership. Kamga et al (2013) studied on temporal (i.e. time of day and day of week) and weather-related characteristics of taxi ridership based on fundamental statistics. All above studies focused on impacts of socioeconomic factors and were lack of explorations in urban built environments. Moreover, a comprehensive study on temporal variances in taxi ridership should be developed based on explanatory other than explorative analysis.

To explore the characteristics of intra-city movement, various methods have been developed. Li et al. (2012) and Moreira-Matias et al. (2013) both introduced autoregressive integrated moving average (ARIMA) model upon availability of taxi GPS traces and achieved the spatial distribution of taxi-passengers for a short-term horizon. However, the ARIMA model was only based on trip frequency and could not explore the causal factors of trips. In a traditional four-step model system, gravity model and radiation model were mostly adopted to complete trip distribution (Guler, 2014; Leung et al., 2011; Masucci et al., 2013). However, the both models only considered effects of distance and populations, and were mostly applicable in analyzing inter-city and international mobility. Ordinary least square (OLS) multiple regression models were also widely used in trip analysis (Jang, 2003; Leung et al., 2011; Qian and Ukkusuri, 2015; Yang and Gonzales, 2014 and 2016). Compared with above methods, OLS multiple regression models could include as many explanatory variables as possible.

METHODOLOGIES

Since the amount of taxi trips is non-negative integers, simply applying the ordinary least squares (OLS) regression may yield improper values (Washington et al., 2011). The proposed model should be carefully selected to account for the count nature of these samples. Moreover, as shown in Table 1, the mean values of taxi trips under all subsamples are much smaller than the variance ($E(y_{ij}) < Var(y_{ij})$). This indicates the potential over-dispersion. To address both characteristics of these samples, the NB is initially implemented which takes the following forms. The Equation 1, exponential function, can account for the nature of non-negative integers. The Equation 2 allows the variance to differ from the mean through introducing over-dispersion parameter.

$$\lambda_{ij} = EXP(\beta_i X_i + \beta_j X_j + \varepsilon_{ij}) \quad (1)$$

Table 1. Descriptive statistics for dependent variable

Samples	Mean	Standard Deviation	Min	Max
weekday morning peak	2.582	22.474	0	767
weekday off peak	2.393	20.435	0	662
weekday evening peak	2.578	20.790	0	626
weekend morning peak	1.089	8.592	0	399
weekend off peak	2.380	18.532	0	525
weekend evening peak	1.095	8.320	0	265
weekday	2.518	21.252	0	767
weekend	1.521	12.749	0	525
whole week	2.233	19.215	0	767

$$Var(y_{ij}) = E(y_{ij})(1 + \alpha E(y_{ij})) = E(y_{ij}) + \alpha E(y_{ij})^2 \quad (2)$$

$$P(y_{ij}) = \frac{\Gamma\left(\frac{1}{\alpha} + y_{ij}\right) \left(\frac{1}{\alpha}\right)^{\frac{1}{\alpha}} \left(\frac{\lambda_{ij}}{\frac{1}{\alpha} + \lambda_{ij}}\right)^{y_{ij}}}{\Gamma\left(\frac{1}{\alpha}\right) (y_{ij}!) \left(\frac{1}{\alpha} + \lambda_{ij}\right)} \quad (3)$$

where, $EXP(\varepsilon_{ij})$ is gamma-distribution error term with mean 1 and variance α^2 ;

$\Gamma(\bullet)$ is gamma function; and

α is over-dispersion parameter (generally using θ represents the inverse of α , instead of α).

Due to the heavily uneven distribution of taxi trips, another issue related to the samples is the existence of excessive zeros that violates normal distribution assumption in NB. In regions with high population density and good economy such as midtown and lower Manhattan, people are more likely to make their trips by taxis. But for places with poor economy condition or far from downtown, people may feel cost-ineffective to ride a taxi and the number of trips may drop drastically. As a result, there are many ZCTAs having no trips during a short time interval and this part of trips should be modeled separately. Alternatively, the ZINB is implemented to address the dual-state system as equation 4 to 6. The zero-inflated count data model provides the flexibility to model the excessive zeros for count data. In the model, there exist two qualitatively different states related to zero observation of taxi trips. One state may result from simply failing to observe a taxi trip during the observation period. The other state may be because of the inability ever to generate a taxi trip between a particular OD pair.

$$y_{ij} = 0 \text{ with probability } p_{ij} + (1 - p_{ij}) \left(\frac{1}{\alpha}\right)^{\frac{1}{\alpha}} \left(\frac{1}{\alpha} + \lambda_{ij}\right) \quad (4)$$

$$y_{ij} = y \text{ with probability } \frac{(1 - p_{ij}) \Gamma\left(\frac{1}{\alpha} + y\right) \left(\mu_{ij}\right)^{\frac{1}{\alpha}} (1 - \mu_{ij})^y}{\Gamma\left(\frac{1}{\alpha}\right) (y!)} \quad (5)$$

$$\mu_{ij} = \left(\frac{1}{\alpha} \right) \left(\frac{1}{\alpha} + \lambda_{ij} \right) \quad (6)$$

where, y_{ij} is the amount of taxi trips from origin i to destination j per observation period.

The over-dispersion parameter α and Vuong's value are used to assess the performance of proposed models. The null hypothesis for the over-dispersion is that the taxi trips are equi-dispersed against alternative of over-dispersion or under-dispersion. The statistics provide the confidence level to 95%. Previous studies suggest the implementation of zero-inflated models if more than 50% of the observations are zero (Lord and Mannering, 2010). A more accepted metric, Vuong's value, is used to measure the appropriateness of ZINB. The null hypothesis for Vuong's value is that all compared models are indistinguishable. The result statistics also provide the confidence level to 95%.

Even for a same significant variable, the effects may vary across different models. One may have a greater influence in one model than that in another model. Measuring these differences will help explore detail and accurate variability in travel patterns. Thus, marginal effect is introduced to differentiate the effects of a same variable in different models. In general, the term measures the effect that a unit change in an independent variable has on the response variable of interest (Miller, 2007). It can provide a good approximation to the amount of change in dependent variables and learn the importance of an independent variable.

DATA and Explanatory Variables

The whole NYC includes 214 ZCTAs distributed in five boroughs: Manhattan, Bronx, Brooklyn, Queens, and Staten Island. Among these ZCTAs, 4 ZCTAs are subtracted due to inclusion of some regions outside of NYC. All ZCTAs in Staten Island that has few observations of pick-ups and drop-offs are seen as outliers and removed. Furthermore, some ZCTAs with small areas (e.g. a particular building) and with few or no population are integrated into their neighborhood to get more accurate estimations. Finally, 168 ZCTAs are achieved as the geographical representation of study area, shown in Figure 1.

One week of GPS taxi data, from 10/5/2009 to 10/11/2009, was sampled, because there was no prominent fluctuation and total trips ranged on an average level during this period. Each day, equipped GPS automatically recorded about 450,000 to 500,000 taxi trips and corresponding travel information, such as origin, destination, start time, and end time. However, GPS records might miss important location information, i.e. longitude and latitude, due to the measurement errors or dense buildings in cities. This will prevent to summary these trips on ZCTA level. Thus, the records with location information missing should be deleted. Moreover, trips originating from or traveling to outside of NYC should also be deleted. The above two deletions will eliminate about 2%~3% of total taxi trips. The next step was to estimate accurate ZCTA values for each record based on ArcGIS. Because many records were without accurate ZCTA values, which influences the aggregated analysis. The matching process in ArcGIS that associates each GPS point with corresponding ZCTAs showed that more than 93% of GPS points could be matched with accurate ZCTAs, comparing with those few original records. To measure temporal characteristics of intra-city mobility, the processed data set was further classified into two groups: weekday and weekend, and under of which three typical time slots are extracted respectively: morning peak (7:00-10:00am), off peak (12:00pm-3:00pm), and evening peak (5:00pm-8:00p). After data pre-

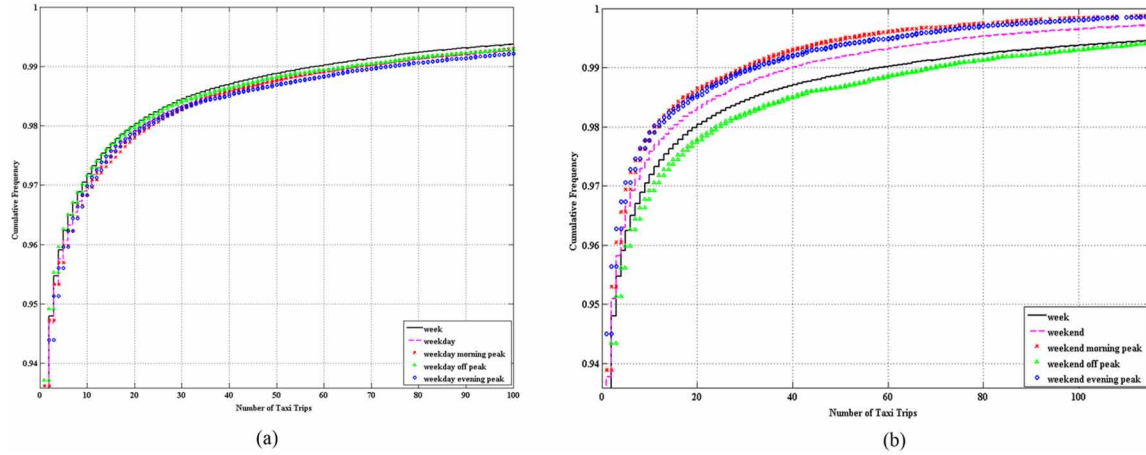
Figure 1. The study area and corresponding ZCTA distribution



processing, the authors could explore intra-city movement under each subsample and compare model estimations to identify temporal variances.

In this study, the amount of taxi trips from one ZCTA to another one was selected as dependent variable. The summary statistics for dependent variables under subsamples were shown in Table 1. The cumulative distributions under subsamples were also shown in Figure 2. From Table 1, it is obvious that the weekday sample has higher mean and standard deviation than the weekend sample. Sample mean are also different under three typical time slots, as well as sample standard deviation. Under weekday, the mean and standard deviation of morning peak and evening peak subsamples are similar and higher than those of off peak subsample. In contrast, off peak subsample has higher mean and standard deviation under weekend. The cumulative distributions shown in Figure 2 also validate the above temporal variability. The cumulative frequency curve of the whole week sample is under that of the weekend sample and above that of the weekday sample, confirming the differences in taxi trip patterns between weekday and weekend. Similarly comparing the cumulative frequency curves, the authors can prove that off peak subsamples are significantly different from the other two subsamples, regardless of weekday and weekend samples. In spite of similar sample mean, standard deviation, and cumulative distributions, morning peak and evening peak subsamples are still extracted separately considering different trip purposes under the two time slots. Thus, the six subsamples are reasonable and enough to explore temporal variability of intra-city movement.

Figure 2. The cumulative distributions of number of taxi trips by OD: a.) the cumulative distributions of number of taxi trips on weekdays, b.) the cumulative distributions of number of taxi trips on weekends



Studied at aggregate level, the attributes of ZCTAs were selected as independent variables. An open dataset (Geodatabase, Version: July 2013) from CUNY provided rich information, for example, 2010 census survey, American Community Survey, and facility locations, were also aggregated at ZCTA level in NYC. Thus, the dataset was used and the authors got 45 attributes, including demographics, socio-economics, transportation and public facilities, and commuters. Another open dataset PLUTO (Version: 13v2) from NYC Department of City Planning was used to extract land use attributes of each ZCTA and the authors achieved 8 land use attributes, including commercial area, residential area, official area, retail area, garage area, storage area, factory area and numbers of units.

However, not all 53 attributes were suitable to account for amounts of taxi trips. A selection of independent variables was developed according to existing literature and from an intuitive point of view. Considering the objective to identify relationships between independent variables and dependent variable. Highly correlated independent variables could reduce accuracy of similar computation. Thus, the authors introduced the multi-collinearity test to further select independent variables and reduce their correlations. In this test, the variance inflation factor (VIF) was computed to quantify the severity of multi-collinearity. Generally, if VIF is less than 10, the selected independent variables could be seen with low multi-collinearity. As a result, selected variables and corresponding VIFs were shown in Table 2.

EMPRICAL RESULTS

In this chapter, the authors use R, a statistical package, to estimate ZINB model. The performance of estimated models is shown in Table 3. The goodness-of-fit ρ^2 of ZINB are all greater than those of NB. The AIC values of ZINB that lesser than those of NB also show ZINB outperforms NB when specifying taxi trips in NYC. The over-dispersion parameter (θ , inverse of α) that are statistically significantly less than 1 show that our data samples have greater variability and are statistically over-dispersed. The Vuongs' values are statistically significantly more than 1.96. This confirms ZINB should be used considering excessive zeros.

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Table 2. Descriptive statistics and VIF values for independent variables

Variables	Description	Mean	Std. Dev.	Min	Max	VIF
DIS	Distance between OD pairs. (km)	13.684	6.940	0	38.183	1.049
Demographics, Social & Economical Variables						
EMP*	Employed population density (km^{-2})	9.252	1.408	-4.605	10.450	7.638
BPL*	Population density who lived under poverty line (km^{-2})	7.439	1.719	-4.605	9.121	6.874
AAI*	Average annual income (\$)	11.053	1.786	-4.605	12.759	3.334
Land Use Variables						
COM	Commercial area (km^2)	1.042	1.162	0.037	7.422	2.998
RES	Residential area (km^2)	1.823	0.994	0	4.519	3.382
Built Environment Variables						
DOR	Density of road (km/km^2)	57.387	38.515	5.892	250.56	1.746
NSS	Number of subway stations	2.732	2.642	0	13	1.705
NOC	Number of colleges	0.679	1.416	0	7	1.291
NOR	Number of recreational sites	1.881	1.640	0	12	1.496
DBL	Density of bike lane (km/km^2)	2.514	2.537	0	12.995	1.744
NCS	Number of city bus stations	68.649	46.572	0	215	3.188
NLB	Number of long distance bus stations	74.696	39.118	0	209	4.125
NOP*	Number of parking	4.310	4.989	-4.605	9.640	2.295

* these variables are transformed based on log function to reduce correlations.

Table 3. Model performances of ZINB and NB

Diagnostics	Weekday			Weekend		
	Morning Peak	Off Peak	Evening Peak	Morning Peak	Off Peak	Evening Peak
ZINB						
Log-Likelihood at Convergence	-66031	-61624	-67809	-25082	-28075	-21207
Log-Likelihood at zero	-93211	-90973	-97511	-34752	-39629	-31137
ρ^2	0.292	0.323	0.305	0.278	0.292	0.319
AIC	132127	123322	135686	50218	56212	42469
θ (t-stat)	0.407 (-57.216)	0.446 (-46.241)	0.407 (-59.787)	0.359 (-42.887)	0.389 (-39.025)	0.492 (-25.880)
Vuong	37.647	23.92	46.802	27.233	30.598	28.476
NB						
Log-Likelihood at Convergence	-70208	-63676	-76963	-27073	-32419	-27267
Log-Likelihood at zero	-93211	-90973	-97511	-34752	-39629	-31137
ρ^2	0.247	0.3	0.211	0.221	0.182	0.124
AIC	140446	127388	153959	54177	64869	64559

Movements on Weekdays

Table 4 presents the model estimation results on weekdays. The results include two parts: the count data part and the excessive zeros part. The count data part mainly determines causal factors that influence number of taxi trips (excluding excessive zeros). The excessive zeros part can explore factors that influence probability of generating and attracting none taxi trips.

The distance of OD pairs has negative effects on number of taxi trips and positive effects on probability of having none taxi trips. The taxi fares are largely correlated to travel distance. Thus, people would prefer to take a short taxi trip, considering relative higher fare rates and total travel cost. Increasing distance will be more likely to reduce number of taxi trips and increase the probability of having none taxi trips.

Table 4. ZINB model estimations on weekdays

Variables	Morning Peak		Off Peak		Evening Peak	
	Parameters	T-Statistic	Parameters	T-Statistic	Parameters	T-Statistic
Count Data Part						
const.	4.350	48.180	3.412	37.151	3.059	32.325
DIST	-1.264	-54.992	-1.038	-41.538	-1.169	-49.330
EMP-O	-	-	-0.023	-2.250	-	-
EMP-D	0.049	3.486	-	-	0.100	5.811
BPL-O	-0.422	-29.416	-0.344	-22.709	-0.290	-19.272
BPL-D	-0.202	-13.604	-0.317	-42.611	-0.373	-20.843
AAI-O	0.131	13.785	0.054	5.615	0.046	4.822
AAI-D	-	-	-	-	-	-
COM-O	-	-	0.490	46.785	0.496	51.359
COM-D	0.734	66.498	0.572	58.428	0.431	47.716
RES-O	0.725	44.161	0.880	46.324	0.911	48.411
RES-D	-	-	0.841	42.448	0.699	46.353
NSS-O	-	-	-0.069	-11.701	-0.039	-5.512
NSS-D	-0.102	-15.959	-0.041	-5.889	-	-
NOC-O	0.167	22.313	0.152	20.778	0.184	24.538
NOC-D	0.259	32.613	0.186	23.041	0.167	21.669
NOR-O	-	-	-	-	-	-
NOR-D	-	-	0.077	9.025	-	-
NCS-O	-0.013	-13.272	-0.016	-20.240	-0.022	-25.820
NCS-D	0.005	7.622	-0.017	-31.983	-	-
NLB-O	-	-	-	-	-	-
NLB-D	-	-	-	-	-	-
Excessive Zeros Part						
const.	-4.149	-23.481	-8.488	-30.669	-8.625	-37.287
DIST	0.310	63.726	3.054	50.244	2.890	54.055

continued on next page

Table 4. Continued

EMP-O	-0.201	-7.055	-0.107	-2.429	-	-
EMP-D	-0.178	-7.206	-0.184	-7.333	-0.149	-5.118
BPL-O	0.681	28.431	0.838	22.565	0.875	33.537
BPL-D	0.505	20.659	0.438	18.073	0.379	14.442
AAI-O	-	-	-0.099	-4.520	-0.166	-8.906
AAI-D	-	-	-	-	-	-
COM-O	-0.820	-34.877	-0.519	-18.361	-0.560	-26.299
COM-D	-0.328	-20.709	-0.324	-17.053	-0.359	-19.965
RES-O	-0.886	-31.547	-0.611	-16.526	-0.752	-23.863
RES-D	-0.852	-29.416	-0.339	-9.481	-0.611	-19.915
NSS-O	-	-	-	-	0.029	2.342
NSS-D	-0.113	-10.596	-0.054	-4.126	-0.062	-6.913
NOC-O	-0.283	-16.513	-0.322	-15.667	-0.291	-18.010
NOC-D	-0.089	-6.906	-0.049	-3.031	-0.078	-5.885
NOR-O	-	-	-0.285	-10.647	-0.172	-10.283
NOR-D	-	-	-0.042	-2.793	-	-
NCS-O	0.012	14.263	0.014	13.005	0.007	5.914
NCS-D	0.008	10.874	-0.009	-8.586	0.006	7.485
NLB-O	-	-	-	-	-	-
NLB-D	-	-	-	-	-	-

Note: *Var-O* means variable at trip origin; and *Var-D* means variable at trip destination.

Employed populations have negative effects on generating taxi trips during off peak and evening peak, negative effects on the probability of having none taxi trips, but positive effects on attracting taxi trips during morning peak and evening peak. The areas with more employment populations are always with various commercial activities and leisure activities. During morning peak and evening peak, the areas with more populations may attract more people to take commercial and leisure activities. However, during off peak, people may work there and few go out. Thus, few taxi trips may be observed at areas with more employment populations. Beyond those, more employed populations are more likely to be helpful in reducing probability of having none taxi trips. The variable may both reduce number of taxi trips and the probability of having none taxi trips during off peak. This may be caused by spatial variability.

The two economic factors, including population under poverty line and average annual income, are also significant. More population under poverty line means most people at the area do not have enough money to maintain a comfortable life. This will reduce number of taxi trips from/to the area and increase the probability of having none taxi trips. In contrast, with higher average annual income, residents can afford the relative higher taxi fares and would like to take this fast, convenient, and comfort mode. This will increase number of taxi trips and decrease the probability of having none taxi trips.

Commercial and residential areas are main trip generations and attractions in cities. They both have positive effects on number of taxi trips and negative effects on probability of having none taxi trips. During morning peak, significant movements from residential areas to commercial areas show that com-

muters are the most important passenger source. With more trip purposes during off peak and evening peak, the movements become more balanced and both areas can attract and generate more taxi trips.

The transit-related variables, including number of subway stations and city bus station, mostly have negative effects on number of taxi trips and positive effects on probability of having none taxi trips. The transit system is competitive and not expensive for most residents, compared with the taxi system. The areas with more subway stations and city bus stations have good transit accessibility and may attract more residents to take transit. This will reduce number of taxi trips and increase the probability having none taxi trips around these areas. However, these negative effects become insignificant when generating taxi trips at these areas during morning peak, as well as attracting taxi trips during evening peak. Interestingly, the areas with more subway stations reduce the probability of attracting none taxi trips. The last mile that passenger needs taxis to connect subway stations and their final destinations may result in this condition.

The public facilities, such as colleges and recreational sites, can also generate and attract more taxi trips that reduce probability of having none taxi trips. College campuses are open to the public and always hold many activities. This may bring more flows and taxi trips. Students living outside campuses may also further increase number of taxi trips at these areas. Recreational sites, as main leisure facilities, can also attract more taxi trips during off peak. In contrast, the positive effect becomes insignificant during morning peak and evening peak on weekdays. After visiting, the recreational sites may generate some taxi trips and reduce the probability of having none taxi trips during off peak and evening peak, though effects on number of taxi trips are not significant.

Table 5 presents the marginal effects of significant variables in estimated models. The authors can further determine temporal variability and the importance of variables through comparing marginal effects. Among significant variables, distance of OD pairs has a greater impact on number of taxi trips and probability of having none taxi trips. And the effects on number of taxi trips become greater during peak hours. However, the effects on probability of having none taxi trips become greater during off peak. There may be some commuters taking long taxi trips. Land use variables, such as commercial area and residential area, also have greater impacts. The commercial area has its greater effects on number of taxi trips during morning peak. This confirmed significant movement to the area at the period. The socio-economic factors also tend to have greater effects during peak hours. For example, employed populations have greater effects on number of taxi trips during evening peak, and populations under poverty line and average annual income have greater effects on number of taxi trips during morning peak. Although with small temporal variance, the effects of built environment variables are more similar.

Movements on Weekends

Table 6 presents the model estimation results on weekends. A little fewer significant variables are identified. Similar as movements on weekdays, the distance of OD pairs also has negative effects on number of taxi trips and positive effects on probability of having none taxi trips. The longer the distance of OD pairs are, the fewer the number of taxi trips may be, but the higher the probability of having none taxi trips may be.

Employed populations have positive effects on number of taxi trips during morning peak and off peak, and negative effects on the probability of having none taxi trips. Different from weekdays, the variable is insignificant during evening peak. This may be because most employed populations may stay at home and take rests instead of going out on weekends. Once going out, they may take the comfort

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Table 5. Marginal effects of significant variables on weekdays

Variables	Count Data Part			Excessive Zeros Part		
	MP	OP	EP	MP	OP	EP
DIST	-0.284	-0.236	-0.261	0.670	0.694	0.645
EMP-O	-	-0.005	-	-0.045	-0.024	-
EMP-D	0.011	-	0.022	-0.040	-0.042	-0.033
BPL-O	-0.095	-0.078	-0.065	0.153	0.190	0.195
BPL-D	-0.045	-0.072	-0.083	0.113	0.100	0.085
AAI-O	0.029	0.012	0.010	-	-0.022	-0.037
AAI-D	-	-	-	-	-	-
COM-O	-	0.111	0.111	-0.184	-0.118	-0.125
COM-D	0.165	0.130	0.096	-0.074	-0.074	-0.080
RES-O	0.163	0.200	0.203	-0.199	-0.139	-0.168
RES-D	-	0.191	0.156	-0.191	-0.077	-0.136
NSS-O	-	-0.016	-0.009	-	-	0.006
NSS-D	-0.023	-0.009	-	-0.025	-0.012	-0.014
NOC-O	0.037	0.035	0.041	-0.063	-0.073	-0.065
NOC-D	0.058	0.042	0.037	-0.020	-0.011	-0.017
NOR-O	-	-	-	-	-0.065	-0.038
NOR-D	-	0.017	-	-	-0.010	-
NCS-O	-0.003	-0.004	-0.005	0.003	0.003	0.002
NCS-D	0.001	-0.004	-	0.002	-0.002	0.001
NLB-O	-	-	-	-	-	-
NLB-D	-	-	-	-	-	-

Note: Var-O means variable at trip origin; and Var-D means variable at trip destination.

Table 6. ZINB model estimations on weekends

Variables	Morning Peak		Off Peak		Evening Peak	
	Parameters	T-Statistic	Parameters	T-Statistic	Parameters	T-Statistic
Count Data Part						
const.	3.969	28.096	3.144	23.576	1.398	13.780
DIST	-1.030	-26.739	-1.116	-30.103	-0.656	-25.420
EMP-O	0.104	5.400	-	-	-	-
EMP-D	-	-	0.075	3.010	-	-
BPL-O	-0.279	-15.298	-0.262	-28.928	-0.201	-22.670
BPL-D	-0.288	-24.005	-0.356	-13.729	-0.196	-17.450
AAI-O	-	-	-	-	-	-
AAI-D	-	-	-	-	-	-
COM-O	-	-	0.430	30.471	0.427	29.490

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Table 6. Continued

Variables	Morning Peak		Off Peak		Evening Peak	
	Parameters	T-Statistic	Parameters	T-Statistic	Parameters	T-Statistic
Count Data Part						
COM-D	-	-	0.486	30.904	0.437	30.040
RES-O	0.551	20.604	0.879	31.891	0.814	29.090
RES-D	0.302	11.265	0.484	18.579	0.547	22.610
NSS-O	0.080	9.031	-	-	-	-
NSS-D	-	-	-0.050	-5.495	-	-
NOC-O	-	-	0.150	12.950	0.154	13.910
NOC-D	0.269	22.177	0.118	8.673	0.131	11.270
NOR-O	-	-	-	-	-	-
NOR-D	0.179	13.406	0.139	10.920	-	-
NCS-O	-0.003	-3.130	-0.020	-19.175	-0.020	-23.330
NCS-D	-0.012	-17.389	-	-	-	-
NLB-O	-	-	-	-	-	-
NLB-D	-	-	-	-	-	-
Excessive Zeros Part						
const.	-6.429	-22.481	-8.617	-22.464	-8.903	-23.422
DIST	2.492	34.516	2.875	35.272	3.199	38.416
EMP-O	-0.095	-2.172	-0.134	-2.288	-0.140	-2.681
EMP-D	-	-	-0.172	-4.252	-0.268	-6.303
BPL-O	0.555	14.369	0.729	14.327	0.782	17.539
BPL-D	0.298	18.755	0.387	10.726	0.533	13.614
AAI-O	-	-	-	-	-	-
AAI-D	-	-	-	-	-	-
COM-O	-1.149	-23.311	-0.546	-17.152	-0.677	-23.640
COM-D	-0.572	-20.072	-0.391	-14.943	-0.317	-12.827
RES-O	-1.115	-22.910	-0.679	-13.689	-0.902	-18.927
RES-D	-0.583	-13.071	-0.681	-13.905	-0.587	-12.412
NSS-O	-	-	-	-	-	-
NSS-D	-	-	-	-	-	-
NOC-O	-0.357	-11.672	-0.236	-9.450	-0.183	-8.374
NOC-D	-0.072	-3.147	-0.111	-5.707	-0.188	-9.284
NOR-O	-	-	-0.192	-6.820	-0.082	-4.081
NOR-D	-0.053	-2.586	-	-	-	-
NCS-O	0.021	15.843	0.013	9.698	-	-
NCS-D	-	-	0.006	5.022	0.013	14.237
NLB-O	-	-	-	-	-	-
NLB-D	-	-	-	-	-	-

Note: *Var*-O means variable at trip origin; and *Var*-D means variable at trip destination.

and fast taxis on weekends considering enough income. Thus, more employed populations can reduce the probability of having none taxi trips.

The economic factor, i.e. population under poverty line, is also significant as weekdays. However, the average annual income does not have effects on number of taxi trips and probability of having none taxi trips. People may be more generous and spend more money than those on weekdays. Thus, average annual income may not have significant effects on taxi trips on weekends.

Commercial areas also have positive effects on number of taxi trips and negative effects on probability of having none taxi trips, as well as residential areas. However, the commercial areas are insignificant during morning peak. This is because most commercial units are still closed on weekend morning and few demands to those areas in early morning. And, the significant movements from residential areas to commercial areas during morning peak cannot be identified on weekends.

The transit-related variables, including number of subway stations and number of city bus station, mostly have negative effects on number of taxi trips and positive effects on probability of having none taxi trips, similar as weekdays. There is only a little different point that number of subway stations has positive effects on generating number of taxi trips during morning peak. This may be because the taxis drive the last mile that connects subway stations with final destination. Colleges and recreational sites also have positive effects on number of taxi trips and negative effects on probability of having none taxi trips. However, the both variables are not significant on generating taxi trips during morning peak, because of very few activities on early weekend mornings.

Table 7 presents the marginal effects of significant variables in estimated models. Among significant variables, the greatest impact on number of taxi trips and probability of having none taxi trips is still distance of OD pairs. And the effects on number of taxi trips become greater during morning peak and off peak. However, the effects on probability of having none taxi trips become greater during off peak and evening peak. Thus, on weekend, residents would prefer long taxi trips and not to take long taxi trips during evening peak. This contradictory condition may be because of spatial variability. Land use variables, commercial area and residential area, also have greater impacts. The commercial area has its greater effects on probability of having none taxi trips during morning peak. The residential area has weaker impacts during morning peak. The socio-economic factors also tend to have greater effects during peak hours. For example, employed populations have greater effects on probability of having none taxi trips during evening peak and populations under poverty line have greater effects on number of taxi trips during morning peak. Although with small temporal variance, the effects of built environment variables are also more similar.

FUTURE RESEARCH DIRECTIONS

With the proliferation of information and communication techniques, pervasive datasets are becoming popular in urban studies, which provides new perspectives for urban dynamics. Most previous studies were based on stated preference surveys that were lack of better spatial and temporal coverage to capture complex dynamics in human movements. However, the condition has been changing by pervasive dataset. For example, the taxi GPS data that records detailed trip-level characteristics and huge trips is widely used to identify movement patterns, estimate link traffic state, and evaluate taxi system efficiency. Except for applications in transportation field, the sustainable urban development also requires supports of large-

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Table 7. Marginal effects of significant variables on weekends

Variables	Count Data Part			Excessive Zeros Part		
	MP	OP	EP	MP	OP	EP
DIST	-0.232	-0.248	-0.150	0.561	0.639	0.733
EMP-O	0.023	-	-	-0.021	-0.030	-0.032
EMP-D	-	0.017	-	-	-0.038	-0.061
BPL-O	-0.063	-0.058	-0.046	0.125	0.162	0.179
BPL-D	-0.065	-0.079	-0.045	0.067	0.086	0.122
AAI-O	-	-	-	-	-	-
AAI-D	-	-	-	-	-	-
COM-O	-	0.096	0.098	-0.259	-0.121	-0.155
COM-D	-	0.108	0.100	-0.129	-0.087	-0.073
RES-O	0.124	0.195	0.186	-0.251	-0.151	-0.207
RES-D	0.068	0.108	0.125	-0.131	-0.151	-0.134
NSS-O	0.018	-	-	-	-	-
NSS-D	-	-0.011	-	-	-	-
NOC-O	-	0.033	0.035	-0.080	-0.052	-0.042
NOC-D	0.061	0.026	0.030	-0.016	-0.025	-0.043
NOR-O	-	-	-	-	-0.043	-0.019
NOR-D	0.040	0.031	-	-0.012	-	-
NCS-O	-0.001	-0.004	-0.005	0.005	0.003	-
NCS-D	-0.003	-	-	-	0.001	0.003
NLB-O	-	-	-	-	-	-
NLB-D	-	-	-	-	-	-

Note: Var-O means variable at trip origin; and Var-D means variable at trip destination.

scale real time data from different departments, as well as advanced and efficient computing techniques. The pervasive dataset will contribute to more details in human movements and urban dynamics in future.

In this chapter, the authors explored the intra-city movement patterns based on huge taxi GPS data. Although ZINB model can account for temporal characteristics of intra-city movement, there are still few limitations that should be studied in future. First, external variables, e.g. number of long distance bus stations, have positive effects on number of taxi trips, but also on possibility of no taxi trips. This may be caused by significant spatial variability. If introducing random parameters, the study can both account for spatial and temporal variability and achieve more accurate results. Second, the used sub-samples only contain 3 typical time slots (morning peak, off peak, and evening peak). This may ignore some important patterns and huge variances in other periods. The authors should include more samples in future to avoid errors from sampling. Finally, more various human trips data should be collected for a better understanding of intra-city mobility. Taxi is a relative expensive mode and trips are mainly with short distance. Not all residents favored this mode. If transit trips data are available and included, the authors can achieve more accurate and meaningful temporal characteristics of intra-city mobility.

CONCLUSION

This chapter focused on exploring temporal variability and causal factors of intra-city movement using taxi geo-location data along with geodatabase. One week of taxi trips data recorded by GPS in NYC were aggregated at ZCTA level. To better understand temporal variability, the authors further extracted six subsamples from the whole sample: including three typical time slots (i.e. time of day: morning peak, off peak, and evening peak) for weekday and weekend (i.e. day of week) respectively. Various attributes of ZCTAs, such as demographics, socio-economics, land use, and built environment, were collected as explanatory variables. Considering count data and excessive zeros, NB and ZINB model were both estimated. The results showed ZINB outperformed NB due to the ability to address over-dispersion and excessive zeroes.

Long trip distance will possibly decrease number of taxi trips and increase the probability of none taxi trips, especially during peak hours. The areas with more employed populations, fewer populations under poverty line, and higher average annual income, are more likely to bring more taxi trips and reduce the ODs with none taxi trips. These significant effects are same as current findings in the literature. However, the temporal variances indicate that the effects are greater during weekday peak hours, but not very significant on weekends. Commercial and residential areas, as main trip generations and attractions in cities, still have more taxi trips. However, the authors further identified significant movements from residential areas to commercial areas during weekday morning peak and insignificant commercial area during weekend morning peak. Number of subway stations and number of city bus stations are negatively correlated with number of taxi trips. However, as a supplement to subway, taxis can also find enough passengers around the areas with many subway stations. Colleges and recreational sites are also two important trip generations and attractions, but have greater temporal variability. For example, no significant movements are observed around these sites during weekend morning, as well as recreational sites during weekday peak hours

The above results provide a good insight in intra-city movement for taxi agencies and department of planning. At strategic level, taxi agencies can track changes in taxi ridership and corresponding spatiotemporal patterns induced by urban dynamics in socioeconomic and planning. With these potential changes, taxi agencies can develop strategic planning for taxi system accordingly. At tactical level, taxi agencies can examine current regulation policies and propose appropriate ones periodically, such as time based pricing scheme considering temporal variances in taxi ridership and appropriate fleet size. Moreover, one of other important potential implications is taxi system modeling. A difficult problem in developing regulations on taxi system is to simulate and model the taxi system, including both occupied and empty taxi trips, and measure potential effects of those regulations. The outcomes of this study can be introduced into modeling of occupied taxi movements. At operational level, the authors can measure reasonable taxi ridership between two regions based on our modeling and then identify those regions with relatively higher taxi ridership. Based on our outcomes, the authors can also develop special customer search strategies under different scenarios, which can be used to train new taxi drivers or taxi drivers with inefficient customer searching strategies.

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KEY TERMS AND DEFINITIONS

Built Environment: A term includes all physical parts of where human lives and works, such as house, buildings, streets, infrastructure, and open spaces. In this chapter, it mainly includes road network, public transportation system, recreational sites, schools, and parking facilities.

Geo-Location: A term refers to the practice of assessing the location or the actual assessed location. In this chapter, it consists of location recorded by GPS.

Intra-City Movement: Human movements occurring within a particular city.

Over-Dispersion: A term in statistics that presents greater variability in a dataset than would be expected based on specified statistical model.

Socio-Economics: A term in social science includes various variables that present individual's or household's economic and social position in relation to others, based on income, education, occupation, etc.

Temporal Heterogeneity: A term is usually used to mark differences in human movements in time.

Zip Code Tabulation Area: A zip code like unit of aggregation for tabulating summary statistics, created by the United States Census Bureau.

Chapter 5

Enriching Geographic Maps with Accessible Paths Derived from Implicit Mobile Device Data Collection

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ABSTRACT

The increasing use of technologies like smart phones and mobile apps enables people to be actively involved in collecting data that can be the base of useful services to the whole citizenship. In the realm of volunteer data collection, this chapter addresses the problem of mobility and accessibility limitations for vulnerable citizens in today's cities. The MEP (Maps for Easy Paths) project proposes a set of tools and mobile apps for the enrichment of geographical maps with information about accessibility of urban pedestrian pathways, targeted at people with mobility problems. Different issues are considered and discussed in this chapter, including: the problem of collecting data of a user's route and of reconstructing it with novel sensor fusion techniques; the problem of correcting the positions obtained from low-cost GNSS receivers of mobile devices; the need of usable and accessible applications for the fruition of the collected data suitable for the target users.

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INTRODUCTION

Emerging technologies, such as wireless sensor networks and internet-based mobile applications, have been reshaping our urban environments, turning them into smart and connected cities. Nevertheless, social, environmental, technological and economical evolutions, have put cities under a constant change, and they have provided citizens with challenges that need modern smart and creative service solutions. Indeed, citizens are the fundamental element of the cities, and smart cities cannot be without smart citizens; from them we are witnessing innovative solutions for their smart cities that do not emerge as top down plans, but rather as bottom up initiatives. Collaboration platforms, open data, open platforms, crowd sourced platforms and the alike, create innovative solutions for city issues through the creativity and collaboration of citizens (Shaffers et al., 2011).

Among the facilitators of this type of social innovations there is the increasing use of smartphones and mobile apps. These technologies have enhanced the connectivity among the population and have enabled people to be actively involved in collecting and exchanging data that can be useful for other citizens and for the city itself. In the realm of volunteer data collection and sharing, this chapter addresses the issue of collecting and redistributing information about mobility and accessibility of city paths to vulnerable citizens in today's cities, and it shows how a collaborative mobile platform can create valuable data to make cities more accessible.

City accessibility is considered a priority in several countries having in mind all people with motor impairments, ranging from users with manual or electric wheelchair to the elderly with/without mechanical support, but embracing also people with temporary reduced mobility such as parents with strollers or people with a temporary injury or illness (e.g., a broken bone).

The number of wheelchair users is difficult to determine; US census estimated 3.6M wheelchair users (1.5% of the population) in 2010 (Brault, 2012; USCensus, 2014); estimates in Europe are very similar ("Wheelchair Statistics", 2016). Besides wheelchair users, a large percentage of the population uses mobility aids or has difficulties in traveling due to old age, disability or reduced mobility. ("Wheelchair Statistics", 2016) reports data from different studies conducted all over the world; data show disability prevalence among elderly people aged 65 and over: the latter represent over 40% of the disabled people. Numbers are expected to grow as well as the age of population; indeed, by 2020, a quarter of Europeans will be over 60. New easy to use tools and services are therefore needed to help achieving an improved accessibility of cities.

Satisfactory solutions for smart city accessibility are still lacking, but the need is clearly increasing more and more as witnessed by the growth of aids to cope with it. Indeed, several collaborative projects have been proposed to improve cities accessibility, through Web or, more recently, smartphones/tablets applications (Bruyninx et al, 2012). However, most of the available applications focus on the accessibility of points of interest (e.g., museums, restaurants, etc.) and they do not offer the information about accessible paths to reach a given, possibly accessible, destination; this is a complementary need for target users. Maps for Easy Paths (MEP in the following) (MEP Project, 2016) is a project funded by Politecnico di Milano under the Polisocial program, which aims at developing a set of tools and mobile apps for the enrichment of geographical maps with information about the accessibility of urban pedestrian pathways for people with mobility restrictions. The project aims at filling the gap between the available information about points of interest accessibility and the unknown accessible paths connecting them by advancing current state of the art in cooperative/social mapping. This is done through implicit data

collection from mobile devices, innovative algorithms for the correction of Global Navigation Satellite Systems (GNSS) position estimates, novel sensor fusion techniques for paths computation and clustering.

The accessibility of city routes (e.g., roads, sidewalks, walkways, etc.) is defined through the active contribution and participation of the target users, which include people with permanent or temporary motor disabilities and, possibly, also active citizens. MEP approach is based on different tools and, considering the final users, it provides two mobile applications for the collection of data from common user mobile devices.

Figure 1 provides a pictorial overview of the project actors and their role within the project. In our scenario target users (i.e., users with disabilities) travel through the city and use their smartphone to automatically collect sensors data (e.g., positions estimated from GNSS satellites, motion sensors data, etc.): to do that, they start an app at the beginning of their journey and stop it when they arrive; no user intervention is required. Being persons with motor disabilities, their route can be considered *accessible* for their type of disability. We assume that a path taken mostly by people with disabilities can be perceived as a friendlier route; this allows us to automatically identify accessible paths.

On the other side, any user (target users or generic active citizens) can instead use a second application, to collect additional data about accessibility (e.g., the presence of a barrier) in an explicit way, by providing a description of the barrier, taking a picture, and so on. This second app is used to visualize to end users' accessible paths, barriers, and other accessible elements (e.g., toilets, transportation stops, parking lots) on a map, to collect ratings about accessibility, and to guide the users through the city. Users profiles play an important goal: the collected data as well as the data visualized on the map take into account also the users' characteristics so that personalized accessibility maps can be provided: e.g., a path travelled by a user requiring step-free accessibility, may be accessible also for users able to climb low curbs.

The two applications are complementary in terms of goals, kinds of target users that can be involved, and kind of information that can be collected.

End users of the tools include all the persons with mobility impairments as well as public entities and associations that may be interested in the possible mobility problems of people with motor impairments

Figure 1. Overview of the MEP project actors



to make best decisions about changes in urban to implement actions to solve architectural problems in the city.

Considering the literature and available applications, several collaborative projects aim to improve city accessibility, through the Web or, more recently, through smartphones/tablets applications; a survey is presented in (Comai et al., 2015). According to this survey, studies targeted at wheelchair users collect user requirements for the identification of barriers or facilitators (e.g., ramps) types but they do not provide prototypes. Papers describing prototypes try to be more general addressing different kinds of disabilities, but put a less effort in the methods used for the collection of real user requirements, focusing more on the description of techniques to provide accessible paths (e.g., they present social network based techniques or techniques for the computation of the optimal path). Considering the status of Web/Android/iOS applications available to the public, almost all of them focus on accessibility of points of interest (like museums, restaurants, etc.). Only some of them include also conditions of sidewalks, presence of cobblestones, conditions of pedestrian crosswalks, curb ramps, street lighting, etc. such as RotaAccesivel (“Rota Accesivel,” 2016), Comuni per tutti (“Comuni per tutti,” 2016), Mapability (“Mapability”, 2016). These proposals are very general and try to address all the disabilities. In the MEP project we have started with motor disabilities and we have focused on all the techniques that allow to improve accuracy of collected results and usability of the final application, advancing the state of the art in the usage of commonly available commercial mobile devices to build accessible maps.

The project is multidisciplinary and in the design of the MEP tools, the following main issues have been considered and novel solutions have been proposed to face them:

1. Path estimates as well as obstacles mapping are held with low-cost GNSS receivers. The positioning accuracy is expected to be quite low; thus, techniques to improve the GNSS accuracy are proposed.
2. For users moving slowly or using a wheelchair, traditional algorithms for path computation based on step detection and dead-reckoning techniques cumulate too many errors and cannot be applied to our target users; a different sensor fusion technique exploiting motion data and low accuracy positioning is therefore required to obtain an accurate path also when GNSS data are not available along the path.
3. From the review of existing prototypes/applications for mapping city accessibility (Comai et al., 2015), we can observe that the most common problems are related to their limited diffusion, lack of user involvement in the whole design process, and complexity/richness of the requirements that should be faced by the application to satisfy all users. Aspects related to the use of technology have been neglected in most of the proposed approaches and applications (e.g., wheelchair users may have restrictions in using mobile devices or generic apps); thus, a user-centered design approach involving users actively in the whole design process has been adopted.

The next sections will first describe in detail the methods and techniques that have been adopted to improve GNSS accuracy and reconstruct the user’s route from the data collected from smartphones; in the second part of the paper we will instead describe the methodology employed in the design of the mobile applications targeted to the end-users.

Overview of the Path Reconstruction Process

Figure 2 describes the process for the collection and computation of the paths travelled by primary users: when a user starts a route, the first app called *MEP-Traces* can be activated to collect along the whole path data needed to reconstruct it. Such data include GNSS positions estimates (at present, GPS and GLONASS), motion sensors data (e.g., accelerometer, gyroscope, etc.) and, possibly, images; all the data are stored on the device SD-Card and are then uploaded on the server for further processing. On the server, since the accuracy in positioning of GNSS data is quite low for mobile device GNSS receivers, GNSS positions are first corrected by exploiting GNSS observations acquired by a receiver installed on a point whose coordinates are known in the area, i.e., a Permanent Station. Then, corrected GNSS positions are fused with motion data to provide a better estimate of the path, especially in those parts of the route where GNSS satellites are not visible; the output of these two steps (GNSS data correction and fusion of GNSS and other sensors data) is an accessible path, which is then positioned in the geographical map to be provided to the final users through the second mobile app, called *MEPapp*. Currently both apps have been developed for the Android platform.

Data Collection through Mobile Devices

The *MEP-Traces* application is used to collect data from common hardware sensors like GNSS, accelerometer, magnetometer, gyroscope, and barometer, which are embedded in the current generation of smartphones and tablets. The application can be configured to collect any subset of the sensors data provided by a mobile device.

Data are collected simultaneously, at the highest possible frequency, and locally stored in the mobile device SD-card. Also images can be collected at a user-defined frequency and used to further improve the sensor fusion algorithm results. Figure 3 shows a snapshot of our Android prototype, showing the images of the backcamera and a set of buttons that are used to: activate the recording of specific sensors or images; configure the application; define one's profile; exit the application. As already highlighted,

Figure 2. Overview of the (accessible) path computation process

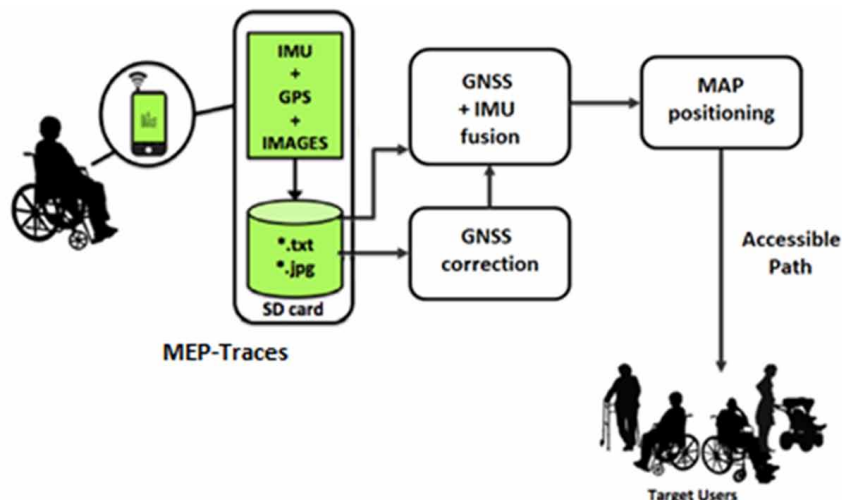


Figure 3. Snapshot of the MEP Traces app for the collection of sensor data



the user profile plays an important role, since we assume that a path taken by people with given characteristics (e.g., manual vs. electric wheelchair users vs. parents with strollers, etc.), could be taken by users with the same characteristics or with lower disabilities.

GNSS and motion sensors data are essential for the reconstruction of the travelled path and should be collected continuously for possibly a long time; indeed, having continuous data from motion sensors and GNSS can lead to more precise information about the location and orientation of the device.

A similar approach has been adopted in (Cardonha et al., 2013) where the *Breadcrumb* application was developed to periodically capture a sequence of measurements based on the device geo-location (i.e., longitude and latitude) without any need for user intervention. To enhance the quality of the collected data, *Breadcrumb* applies a simple moving average over the last 10 estimates of the device velocity and it identifies slowdowns as obstacles. Compared to *Breadcrumb*, in our approach we try to extract as much as information as possible from the available sensors fusing the GNSS with the inertial data in order to reconstruct the exact path of the user, as explained next.

Path Computation from Mobile Sensors Data

Given the data captured from an arbitrary number of sensors, we are able to reconstruct the user path. To this extent, we use a Gauss-Newton approach to sensor fusion (Cucci & Matteucci, 2014b) which applies nonlinear calibration techniques to estimate possibly unknown parameters related to the acquired sensors: for example, if along the path for a given time the GNSS sensor signal is sparse or absent, we can estimate its values by exploiting other motion sensors data.

In the MEP architecture, sensor fusion is performed by the *MEP*-Fusion engine which reconstructs the path followed by the user applying a sensor fusion algorithm based on the ROAMFREE library (“ROAMFREE”, 2016), which was modified and enhanced to accommodate for sensors like those found in the mobile devices. ROAMFREE (Robust Odometry Applying Multisensor Fusion to Reduce Estimation Errors) (Cucci & Matteucci, 2014a) (Cucci & Matteucci, 2014b) is a framework developed originally for autonomous robot navigation at the Artificial Intelligence and Robotics lab of Politecnico di Milano. The framework offers a library of sensor measurement models, a tracking module, and a

calibration suite that allows the estimation of unknown sensor parameters. Even if originally designed to fuse sensors measurements in order to determinate the position and orientation of a mobile robot, thanks to its general approach it has been used in the MEP project for tracking mobile devices based on a variable set of motion sensors measurements. ROAMFREE divides sensors into different categories according to the type of measurements they provide: absolute position and/or velocity, angular and linear speed, acceleration and vector field (e.g., magnetic field, gravitational acceleration). For each of these categories an error model exists, which relates the current estimate of the device pose to the measurement data, taking into account common sources of distortion, bias, and noise.

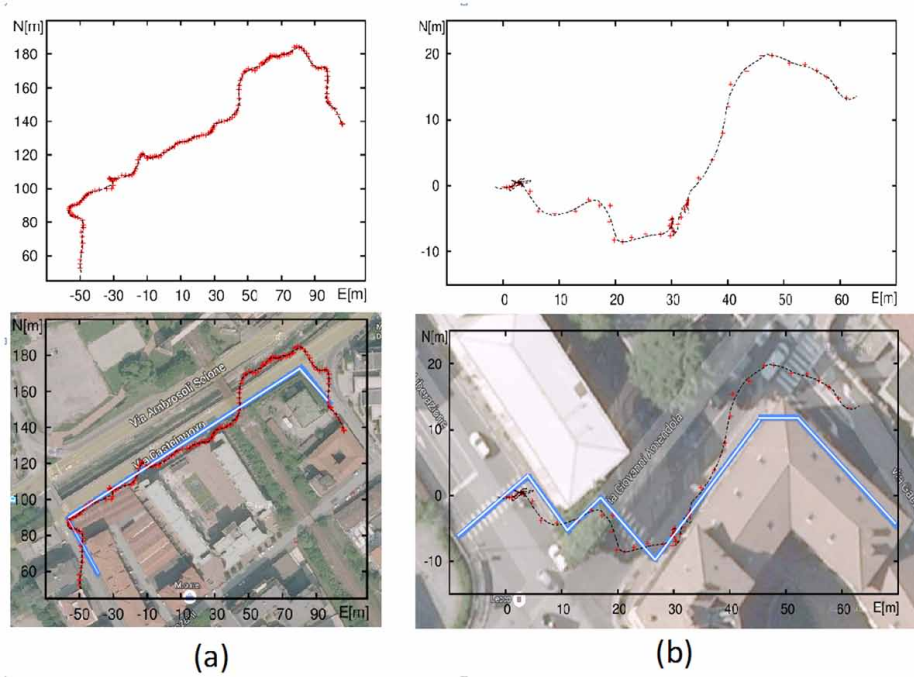
ROAMFREE sensors used in the MEP-Fusion engine are the global positioning system (GPS), the accelerometer, the gyroscope and the magnetometer, together with the associated calibration parameters. To be processed by ROAMFREE, sensors data obtained from the *MEP-Traces* application must be first preprocessed and filtered: first, we use a Savitzky-Golay filter (Savitzky & Golay, 1964) on the accelerometer and gyroscope measurements to reduce their noise; then, since the Android operating system provides sensor data using an event-based sampling schema, we create splines out of the obtained filtered data to perform a fixed frequency sampling, as required by the sensor fusion algorithm of ROAMFREE. The main differences between a robot and a mobile device are represented by the quality and the heterogeneity of the sensors. In our approach we had to take in account the fact that we will receive measurements from different sensors from different devices, each one with slightly different characteristics, therefore calibration could not be done beforehand.

Experimental Results

In our preliminary experiments, data have been collected using an LG G2 (D802) mobile phone at different locations. The next examples, show the results obtained in Lecco (with a path starting and ending approximately at $45^{\circ} 50' 58.7''$ N, $9^{\circ} 23' 30.0''$ E and $45^{\circ} 50' 59.1''$ N, $9^{\circ} 23' 43.1''$ E, respectively) and in Como (with a path starting and ending approximately at $45^{\circ} 48' 06.0''$ N, $9^{\circ} 05' 31.1''$ E and $45^{\circ} 48' 09.3''$ N, $9^{\circ} 05' 317.4''$ E, respectively). During both acquisitions the user held the mobile phone pointing forward horizontally with the main camera on the left, as suggested by the application user interface. Pictures have been collected during the journey together with raw motion sensors data and GNSS estimates too; even if not currently implemented in the sensor fusion algorithm yet, the integration of images in the trajectory reconstruction process could improve the quality of the overall estimate further, and it is foreseen as the next step of our work. If we were not interested in continuously taking pictures, the mobile phone could have been held freely by the user since the ROAMFREE library is able to reconstruct the trajectory using the absolute reference frame of the GNSS and the orientation provided by the Earth magnetic field recorded by the magnetometer. Nevertheless, a swinging device, like being held in a hand following the movement of the body or in a pocket, would have been more difficult to track in an accurate manner.

Results obtained by applying the sensor fusion algorithm are shown in Figure 4: the pictures show the trajectories of the two routes reconstructed using the fusion algorithm and their overlay on a map with the real paths (represented with white lines). The red crosses on the trajectories represent the locations where GNSS data are received. The higher concentration of GNSS samples in Figure 4(a) is an apparent effect due to the difference in scales of the plots; the path in Figure 4(a) is simply longer than the path in Figure 4(b).

Figure 4. Examples of reconstructed trajectories with plots of the trajectories (in the upper part) and the reconstructed trajectories (in the lower part) overlaid on the map with the path taken by the tester (white line)



According to this experiment, the results of the fusion process is quite satisfactory: provided a good accuracy of the estimated GNSS positions, it is possible to recover for missing or sparse measurements thanks to the integration and self-calibration of motion sensors. At this stage we are not reporting the results obtained by improving the GNSS accuracy through the use of a known fixed Permanent Station, but we have focused only on the effectiveness of sensor fusion.

The next section describes possible techniques to improve GNSS accuracy, to be used both for trajectories collected along the path, or when a barrier is signaled by a user in a particular position (e.g., with a picture associated to its GNSS position).

The correction of Standard Point Positioning

In Standard Point Positioning (SPP), a GNSS receiver (in the following named *rover* to be consistent with the relevant literature) processes the raw data (observations) acquired by all the satellites in view to estimate its position: the estimation is performed in a single epoch in real time (Leick, 2014; Hofmann-Wellenhof, Lichtenegger, & Wasle, 2008). In our case, the rover is a GNSS chipset embedded in a smartphone or tablet.

In mapping paths, obstacles, points of interests, or any other object, the problem is not only to estimate accurately their correct coordinates, but it is also to correctly represent them in maps and for this reason two kinds of problems must be faced.

Firstly, the estimated positions contain errors that are due to the propagation of individual (at the satellite level) errors existing in processed observations. Moreover, the propagation of the individual errors in the estimates depends also on the quality of the spatial configuration of the satellites with respect to the rover: the so called DOP (Deviation Optimum Percentage) indexes are computed and used to quantify it. The accuracy problem can be significant in urban scenarios, like the one faced by the MEP project, where satellites visibility is obstructed by buildings (urban canyons).

Figure 5 shows typical blunders and random errors present in urban estimated trajectories.

At a second level, a map can contain errors, and this is true in particular for maps that are globally and freely distributed by Web services. In this case, right coordinates and trajectories are wrongly represented in it, and their alignment to the map is needed. In this regard, OpenStreetMap (OSM) (Bennett, 2010; “OpenStreetMap”, 2016) has been chosen as reference cartography for MEP. OSM is a collaborative project to create a free editable map of the world; its vector data can be accessed and used to georeference and map GNSS results. Furthermore, in OSM the cartography can be corrected and modified where needed and the corrections can be shared with the worldwide community, contributing to the growth of the project.

In MEP we have investigated the problem of improving the accuracy of GNSS to provide a better input to the MEP-Fusion module described previously. In particular, two main goals have been addressed:

- Assessment of the accuracy of GNSS chipsets embedded in smartphones and tablets, and
- Techniques to improve the positioning accuracy of smartphones and tablets.

Figure 5. Examples of GNSS trajectories estimated with a Samsung tablet in Como (IT) town



Accuracy Assessment of SPP with Smartphones and Tablets

A test path in urban scenario has been identified as shown in Figure 6; it is 6,4 Km long and it has been chosen to represent different conditions of satellite visibility:

- Urban canyons (old town),
- Areas of mediocre visibility (outside old town), and
- Open areas (near the lake).

The path has been surveyed three times; in each survey, one (high cost) geodetic receiver and one test smartphone have been carried. The observations of the geodetic receiver have been post processed in kinematic modality with respect to the COMO Permanent Station, belonging to the European Permanent Network (EPN - Bruyninx et al., 2012), using Leica Geomatics Office (LGO), a software of Leica Geosystems (<http://www.leica-geosystems.com>). LGO combines common observations from the reference station and the moving (rover) receivers in double differences (Leick, 2014; Hofmann-Wellenhof, Lichtenegger, & Wasle, 2008) to estimate the rover trajectory. At first, double differences code solutions are provided, then, double differences phase observations are combined and processed: the so called float solution provides intermediate results while the fixed solution provides the final ones. The accuracy of phase fixed solutions are typically of some centimeters, while the accuracy of float solutions is at the

Figure 6. Test path in Como town



decimeter level. Code solutions accuracies are worst, up to the meter level. To obtain fixed solutions, fair observation conditions are needed; in mediocre conditions, processing could stop just with codes. This is the case of our processing: in open area, typically phase fixed solutions are obtained while in urban canyons, often only float or code solutions are available.

The estimated and stored real time SPP positions of smartphone have been downloaded and compared with LGO post processing. Considering the different accuracies of phase fixed and code solutions, comparisons are separate. Table 1 shows the statistics of the differences between the double differences phase fixed reference solutions and the smartphone solutions. Comparisons show accuracies of few meters, that are consistent with the accuracy declared in the literature

Double differences code solutions cannot be used as reference for testing purposes; in any case, some analysis is worth even for these data.

Table 2 shows the statistics of the differences between these solutions and the real time SPP smartphone positions. The statistics are generally quite mediocre and significantly worse than the previous: root mean squares (RMS) doubles and the ranges between minimum and maximum differences are of several meters. This is caused by two problems:

1. Double differences code solutions are significantly less accurate than phase solutions; and
2. Post processing provides only code solutions in sites/streets with mediocre observations conditions; in these cases, clearly also the smartphone SPP works worse.

Table 1. Statistics of the differences between post processed double difference phase fixed solutions and real time smartphone positions. RMS: root mean square of the differences; Max: maximum difference; Min: minimum difference

	Survey 1		Survey 2		Survey 3	
	East [m]	North [m]	East [m]	North [m]	East [m]	North [m]
Mean	0.3	-0.2	-0.4	-3.1	1.1	-0.3
RMS	2.4	2.5	3.7	5.3	3.9	5.0
Max	14.1	11.5	9.9	14.4	14.0	19.4
Min	-7.8	-14.3	-10.8	-16.6	-12.8	-8.3

Table 2. Statistics of the differences between post processed fixed phases LGO solutions and real time smartphone positions. RMS: root mean square of the differences; Max: maximum difference; Min: minimum difference

	Survey 1		Survey 2		Survey 3	
	East [m]	North [m]	East [m]	North [m]	East [m]	North [m]
Mean	-0.3	-0.6	-2.1	-1.5	1.5	-1.6
RMS	6.2	7.4	6.8	7.4	6.7	10.7
Max	31.0	25.7	18.9	27.4	31.2	31.6
Min	-57.6	-82.5	-53.7	-27.5	-22.3	-65.3

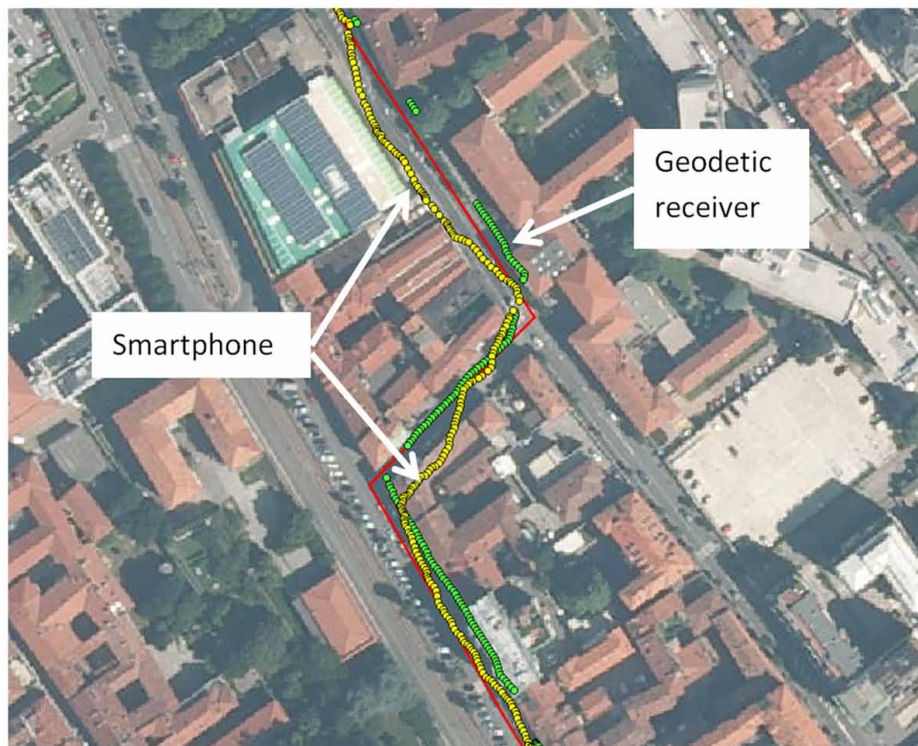
One example is shown in Figure 7 where the true trajectory is plotted in black. In the middle, post processed code solutions obtained from the geodetic receiver provide acceptable estimates, while smartphone trajectory clearly deviates. However, in the lower and partly in the upper part of the path, both the solutions clearly deviate from the true trajectory.

Techniques to Improve the Positioning Accuracy of Smartphones and Tablets

Two approaches are proposed in the scientific literature to improve the accuracy of SPP: relative positioning, as synthetically described in the previous section, and Precise Point Positioning (PPP) (Kouba & Heroux, 2001). The former has been considered for MEP purposes since it only requires GNSS observations acquired by a receiver installed on a point whose coordinates are known, i.e., a Permanent Station, beside the data acquired from the device to be corrected.

To understand the relative positioning principle, one premise is needed; GNSS errors in observations can be classified in spatially correlated and spatially uncorrelated. Spatially correlated errors are similar in near observation sites: atmospheric (tropospheric and ionospheric) delay is their main source. On the contrary, uncorrelated errors vary abruptly and they can be significantly different even in very near sites; on this side, multipath is the main source.

Figure 7. Trajectories of geodetic receiver and smartphone compared with theoretical trajectory (straight red line) in mediocre observation conditions



Typically, spatially correlated errors dominate the error budget. Relative positioning aims at their reduction by exploiting the knowledge of permanent station position and the processing of the combined data of permanent station and rover; it can be implemented by three different methods.

- **M1:** Corrections to the positions. The rover processes the code observations acquired by all the satellites in view to estimate its position, then the positioning errors are estimated and corrected by a specific processing of the permanent station observations.
- **M2:** corrections to the observations. the individual errors in the permanent station code observations are estimated, and they are removed from the relevant code observations of the rover. finally, the cleaned rover observations are processed to estimate a position.
- **M3:** Relative positioning. The code observations of the permanent station and the rover are combined, typically by double differencing, to estimate the baseline between the two receivers: the known position of the permanent station and the estimated baseline provide the estimated position of the rover.

All the methods can be implemented both in real time and in post processing. Moreover, the processing can be performed either user side or server side. It is well known that the first method provides less accurate results than the others; however, it requires only the estimated positions by the rover, while the others require also its raw observations. When the correction refers to the processing of chipsets embedded in smartphones and tablets, only the first method can be implemented since these chipsets internally process raw observations, but they output only the estimated positions. For the purpose of the MEP system, no real time is needed; indeed, the crowdsourced data can be corrected once they have been uploaded on the MEP server. Once they have been corrected, MEP-Fusion processes them and only after they have been fused with motion data they become available to the other users. An off line, post processing approach has been designed.

A generic observation session is considered, that can last from few seconds (epochs) to several hours. For the whole session, the GNSS chipset estimated positions are available in National Marine Electronics Association (NMEA) format. In particular, for each epoch of the session, the following information are needed:

1. The position, and
2. The list with the identifiers of satellites used in the positioning.

For the whole session, the permanent station code observations are available in Receiver INdependent EXchange (RINEX) format. A standard hypothesis is that for each epoch, the observed satellites by the rover are a subset of the permanent station dataset: indeed, typically permanent station s are installed in sites with optimal sky visibility, like the roofs of high buildings, while the rovers operate on the ground. The following procedure is iterated for all the epochs of the session.

1. Given one epoch t , the list of the satellites observed by the rover are read.
2. The permanent station data are read: only the code observations of the satellites observed also by the rover are selected.
3. The selected subset is processed to estimate the position of the permanent station.

4. The estimated position is compared with the known one: the differences represent the estimation error at epoch t .
5. The error is subtracted from the estimated position of the rover at epoch t , in order to correct it.

Clearly, only the processing of the same satellites can guarantee that the errors in permanent station and rover estimated positions are similar: therefore, step 2 is strictly needed. However, even when the permanent station and the rover are near, the spatially correlated errors can propagate slightly differently. Moreover, errors in positioning depend also on the processing parameters and strategies: the off line processing algorithms and parameters adopted for permanent station data must be carefully tuned to be as much as possible consistent with those typically implemented in smartphones chipsets. This constitutes the first weakness point of the proposed method.

Several low cost (≤ 500 Euro) GNSS chipsets are available on the market that output both codes observations and estimated positions. At present they are not embedded in smartphones and tablets, but their future use for mapping applications could be foreseen, at least at the experimental level. Therefore, also the third method has been investigated for future use in the MEP system.

1. Given an epoch t , the code observations of the rover and the permanent station are read.
2. The observations are combined in double differences.
3. The double differences are processed to estimate the baseline between permanent station and rover.

The implementation and comparison of the two approaches is currently in progress. Many parts of the needed processing software are already available as Free and Open Source Software (FOSS) programs or libraries, like goGPS (“goGPS Project”, 2016; Realini, 2009; Realini & Reguzzoni, 2013) and RTKLib (“RTKLib”, 2016; Takasu & Yasuda, 2009); for the MEP purposes, they need to be tuned and embedded in one automatized software. Correspondingly, all the new implemented software will be freely published according to FOSS standards.

One last remark is worth. From a GNSS point of view, the proposed method is not a novelty. Indeed, the corrections to the positions and to the observations is already described in the aforementioned references and implemented in many applications. In particular, similar principles are implemented by the USA Wide Area Augmentation System (“WAAS”, 2016) and by the European Geostationary Navigation Overlay Service (“EGNOS”, 2016). Indeed, these systems provide corrections streams that are computed typically at a regional scale and can be used both in real time and in post processing to correct the positioning of a rover. However, the real time use of WAAS, EGNOS and similar systems requires several additional features and communication channels in the GNSS rover, that are not implemented in chipsets of smartphones and tablets. On the contrary, our approach is based on a server side automated processing of the positions estimated in real time by rovers: therefore, it greatly simplifies the procedure from the user side. Moreover, our approach is based on the use of a local permanent station instead of generalized regional corrections: therefore, at the local scale, it models better and corrects spatially correlated errors.

User-Centered Design of the User Experience

The previous techniques are used to collect, process, and improve sensors data to reconstruct accessible paths, with minimal intervention of the user. The main mobile application (*MEP* app) instead provides

different functionalities for any kind of user, from the visualization of the collected data about collected accessible paths, to the request of paths to a given destination, to the report of obstacles/barriers, etc.

To foster the sustainability of the whole process, User Experience (UX), which is related to the context of use and user behaviour, plays a fundamental role in the application design, especially with target users with specific needs. Designing UX for mobile applications requires a detailed investigation on the user, since UX is not only correlated with the characteristics of the interface such as usability, functionality, complexity, but also with the user emotional state, the environment of use, and the social setting, in which the interaction happens. These are important aspects that have to be taken into account while conducting tests with users of interactive systems (Hassenzahl & Tractinsky, 2006). According to Jordan (Jordan, 2008), user experience is based on *functionality* - that is related to the satisfaction of user needs, *usability* - that is related to be easy to use, and *pleasure* - that is related to user's affective state while using it. Pleasure is one of the subjects that is complex to measure and correlated with various aspects in the user behaviour, such as physio, socio, psycho and ideo (Jordan, 2008). A user experience that depends on user affective respond and subjective perception (Aaron, 2013) is one of the goals that the MEP project aims to improve.

In order to understand user needs and their perception on the experience, one to one contact with users is crucial for designers. To account for this, the MEP project is based on a user-centred design approach that involves users actively in the whole design process.

In this section we explain the user-centred design process adopted in MEP, which in its earlier phases includes user need identification with focus groups, persona development, user-scenario building, followed by wireframe construction, interactive mock-up building and preliminary user test to evaluate the application before its final implementation (see Figure 8).

Focus Groups

Focus groups are group discussions led by a moderator in order to get qualitative data about a topic in the different phases of the design process, from concept development and discussion of ideas to prototype evaluation (Bruseberg & Mcdonagh-Philp, 2001). In the MEP project, three focus groups with different user characteristics (i.e., manual wheelchair users, electric wheelchair users and elderly people) were conducted. Focus groups were held in home-like environments, where participants could feel comfortable, with the participation of a psychopedagogue from the CRAiS association ("CRAiS", 2016), who acted as moderator, and of the design researchers of the MEP team.

The focus group consisted of different sessions: in the first one, participants answered questions about accessibility problems with the support of architectonic obstacles pictures.

In the second session, a brainstorming was organized, to envision and co-create the app based on target users' ideas, needs and values. To trigger their imagination, two examples of applications displaying different accessibility features (namely "ComuniPerTutti" (2016) and "Mapability" (2016)) were shown

Figure 8. MEP user-centred design process



and experienced on tablets and smartphones during the focus groups. While ComuniPerTutti shows architectonic obstacles on the city map with icons of different shapes and colours, Mapability provides also a bird-eye view with red, yellow and green lines that indicate the accessibility of sidewalks (see respectively Figure 9 and Figure 10). By exploring these two interfaces, the participants reflected their opinions and ideas for an appropriate solution. During the tests with such interfaces, their behavior was observed and analyzed.

In particular, answers given during the focus groups were analyzed based on *grounded theory* that is described as a set of methods for collecting and analyzing qualitative data by means of clustering and categorization in order to build theories *grounded* on that data. As a first step, *open coding*, i.e., the part of the analysis concerned with identifying, naming, categorizing and describing phenomena found in the text, was done. Besides, *memoing* was done by taking notes in order to aid MEP researcher to conceptualize observations and collected ideas.

Figure 9. Snapshot of the ComuniPerTutti interface

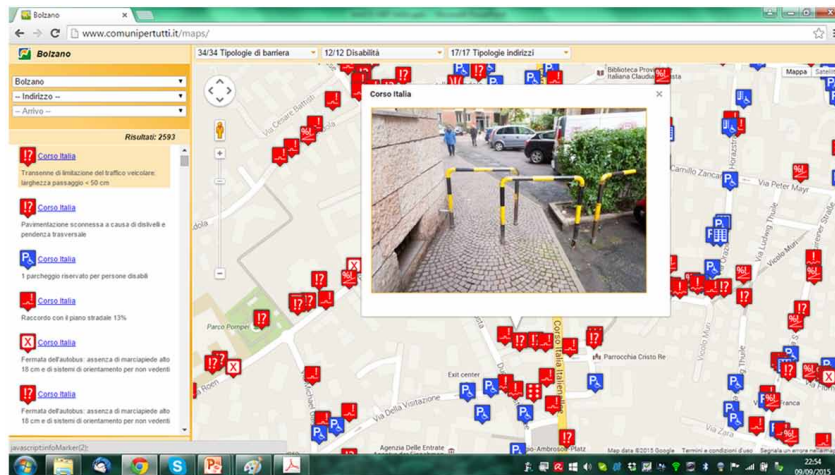
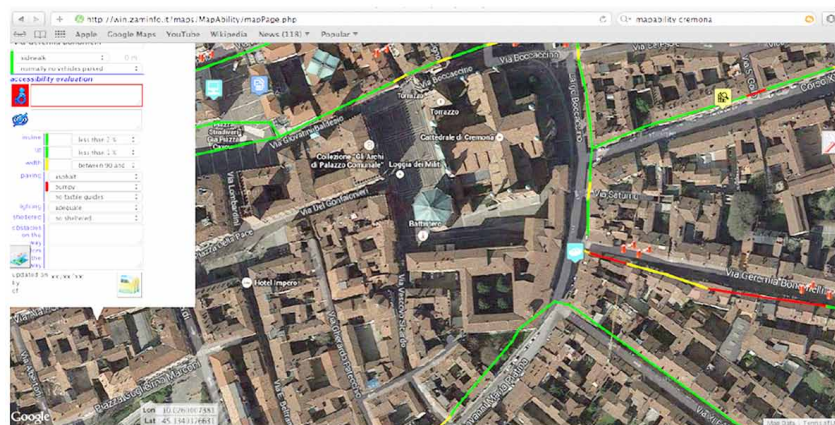


Figure 10. Snapshot of the Mapability interface



The focus groups were recorded as audio files, later analyzed to create codes based on the words and groups of words reported by participants. The audio files were turned into digital text files, in which codes were highlighted (Figure 11). These codes were categorized into different concepts that were reflected in the app design in the design process.

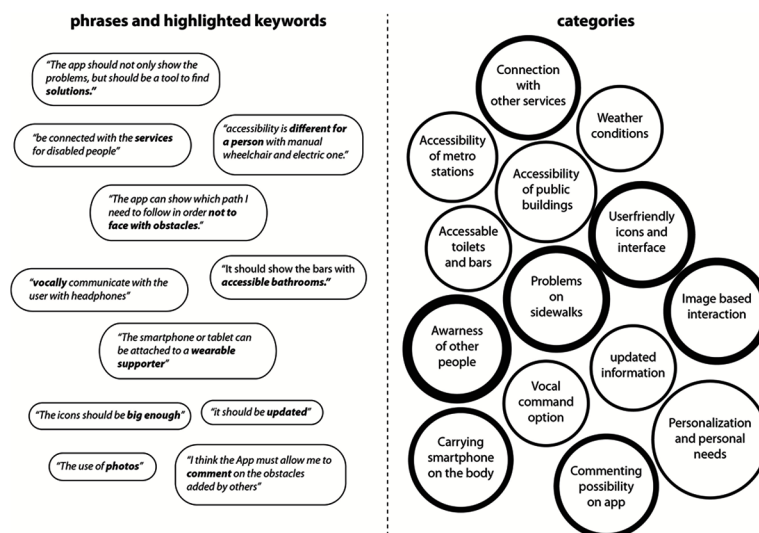
Focus Groups Results

The Elderly Focus Group consists of five participants, who are in average 72 years old, one female and four males. They are all Internet users and four of them use smartphones and tablets in their daily lives. They have active working-social lives, in which they always move in the city. They use social network platforms (such as Facebook), and email to get in contact with friends and family members.

In the first half of the focus group meeting, they mentioned several accessibility problems. They stated they become panic and anxious when they go to a new place: streets can have various architectonic barriers and not knowing them in advances creates some stress on them. They feel more comfortable to follow the paths that they already know. They mentioned that they prefer metro stations with escalators and therefore information about the availability of escalators would be very helpful to plan their journey in the city. Besides, weather conditions could affect the city's accessibility as well. Beside architectonic barriers, also people can cause serious problems, such as people cycling or parking on the sidewalks. One of the participants stated that the services that are provided are also important facts, which make the city accessible: for example, if the city offers special services for the mobility of disabled people, this would be an important information to know about. They mentioned that, since obstacles could be difficult to eliminate, it would be better to know how to arrive to a destination without bumping into any obstacle: "if we cannot eliminate the obstacles, we go around them!"

During the experience with two interfaces they commented on their usability. They preferred the interface of ComuniPerTutti, being more interactive and user-friendly. They appreciated the availability of photos immediately when clicking on the obstacle. They stated that the Disabled Parking icon was very

Figure 11. Categories and analysis on coded data (the thicker circles are more mentioned concepts)



useful for them, because it is often difficult to find parking places for disabled people. In the interface of Mapability they had difficulties to click on the lines. Since elderly group has problems with seeing fine details, the test with two interfaces showed that the app should be designed in a way that icons and clickable elements are big enough. On the other hand, while using the interfaces on tablets and smartphones, they stated that they would need a wearable system, which can hold the device while walking in the city. Some of the participants mentioned that they would prefer an audio navigation system, which guides them in the city and warns about obstacles.

The Electric Wheelchair Users Focus Group consists of four participants (all males). They have restricted hand movements at various levels of severity from low to high. They use mini joysticks and buttons attached to their wheelchairs in order to control the wheelchair and, at the same time, to interact with their computer and smartphone via Bluetooth connection. The locations of these controllers vary depending on the user disability. While one participant uses a button under his head, the other three participants use the joystick and other buttons located on the arm of the wheelchair. With the joystick they can only control one device at a time, hence they cannot use the smartphone when they are on the move.

In the first half of the focus group, participants highlighted the importance of information about accessible metro stations that have escalators or elevators. They also mentioned that during their move in the city, they often need to go to a bar with an accessible toilet, hence information about accessible toilets would be very useful for them to plan their journey in the city. They remarked also that the type and width of the sidewalk is very important for electric wheelchair users.

During the second stage of the focus group, when they tested the two interfaces, they had difficulties in clicking on the lines and icons in both interfaces and zooming in and out was problematic as well. Due to the fact that this group needs to interact with the app by a Bluetooth device, rather than hand gestures, the app should be designed considering mouse clicking action. Having gesture-based features might not work when a disabled person uses the app with a mini joystick connected to their electric wheelchair. They stated that data quality and accuracy could be improved with a commenting system, in which the users are controllers of the data. They mentioned that reading comments of other people in an online platform could create reliability. This information is useful to understand their concerns about crowd-sourced platforms.

The Manual Wheelchair Users Focus Group consists of six participants (four males, two females). One of the participants has finger movement limitations while using tablets or smartphones, for example performing zoom in and out or typing with digital keyboards. Three of the participants always go around with a companion, and other three can autonomously go around with their manual wheelchair. In the first session of the focus group, the participants pointed out that each type of wheelchair (manual, manual with a companion, or electric) has different difficulties during the move and the obstacles can vary depending on the type of the wheelchair. Due to the fact that their speed depends on their own hand force, compared to electric wheelchairs, crossing the streets can be problematic when the two sidewalks are very distant from each other. The other main problem they referred was related to irregular sidewalks, such as tiles, stones, and sidewalks without slopes. In the second session of the focus group, after they tested both interfaces, they reported that they found the indications of Mapability complicated, and they preferred the ComuniPerTutti interface that shows photos when clicking on the obstacle icons. Three participants are regular smartphone users and they were comfortable to interact with both interfaces without any problem. On the other hand, the ones that need companions to move around the city stated that they

often do not use the smartphone, but their companion uses it to navigate in the city. This information gave rise to include also the companions into the target group of app users. Besides, they mentioned that the app should be updated often and used by active users in order to give reliable data, therefore sustainability of the platform is an important issue.

Persona Development and User-Scenarios

Before starting the design of the MEP mobile application, user-scenarios and personas were created in order to place the application in a story setting. These stories and personas were constructed based on the focus group results, which gave an idea about the user profile, their routines while using their mobile phones, and the accessibility problems they face with in their daily lives. Scenarios aim at helping the design process to understand the user experience, needs, and desires in a constructed fiction that reflects the reality.

The results of the focus groups were used in order to create three personas, i.e., fictional characters that help designers to create the user scenario and to illustrate how user would use the end product. While this tool provides designers valuable inputs to create user-scenarios, it also contains clues that are useful to design the user interface of the mobile application (see Figure 11). In the figure, among the collected information, each persona visualizes the main characteristics of that user type, the usage of different device types (smartphone, pc, tablet), and the usage of different means of transport.

From these personas, three user-scenarios were constructed in order to understand the possible interaction steps (see Figure 12). Each scenario explains the important steps of user interaction with the mobile application and helps designers to create the wireframes that are the basis for the application design. In particular, Scenario 1 is targeted at electric wheelchair users and describes how to get accessible directions to a destination; Scenario 2 is targeted at manual wheelchair users and gives an idea of how to get information about the surrounding area, for example, to find a parking lot for disabled people; Scenario 3 is targeted at the elderly and represents the case where a person checks the accessibility of a path and evaluates possible obstacles before taking that route.

After the creation of user-scenarios, wireframes were developed, first by hand sketching (see Figure 13). Wireframes are visual design tools that identify the content and the navigation of the pages in the application design. Following the wireframes, a user interface has been designed and an interactive mock-up was created to be evaluated in a preliminary user test.

Figure 12. Examples of three personas, one for each user type (electric wheelchair users, manual wheelchair users, elderly)

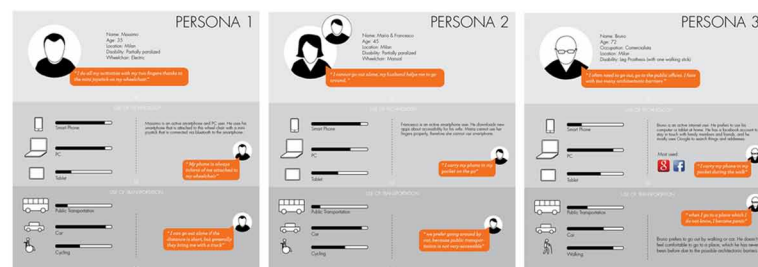
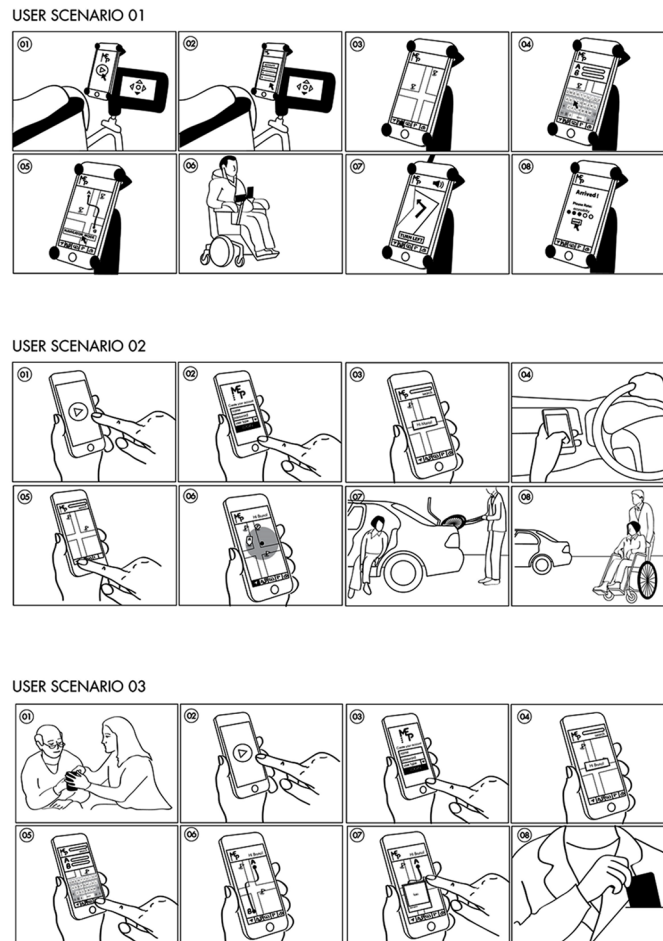


Figure 13. Three user scenarios based on three personas



Preliminary Design Solutions and User Test

Based on the wireframes, the pages of the application were designed, and an interactive mock-up was built to simulate the app (see Figure 14). While the obstacles are shown with yellow icons, the accessible paths and public transportation stops are displayed in green. The main menu is composed of six different icons, indicating different sections of the application design (e.g., map view, nearby view, etc.). Each section name is displayed on the top of the page, while the corresponding menu icon is highlighted. The app is designed to have a simple interface that avoids long and technical explanations about the obstacles, and it rather uses photos and simple icons. The interface allows users to add comments and evaluate the obstacles added by other people; therefore, it has an interactive attribute that gives user an active role (see Figure 15).

The mock-up has been evaluated in two user-tests with the electric wheelchair and the manual wheelchair users. Before the user test, the participants watched a video tutorial about the use of the MEP app. After the demo, the participants were asked to navigate and accomplish the following tasks with the interactive mock-up shown on a smart phone screen:

Figure 14. Wireframe: Hand sketches

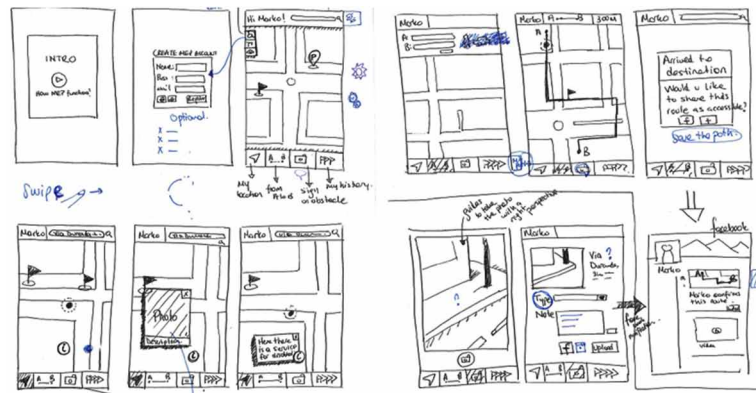
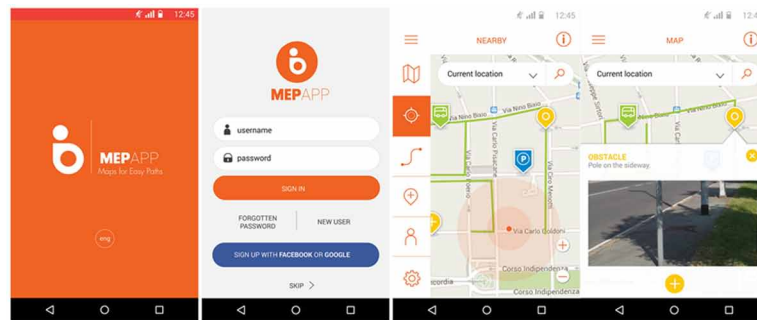


Figure 15. Some pages from Mock-up of the MEP app



Task 01: Registering as a new user.

Task 02: After registration, open the general map and select an obstacle.

Task 03: Evaluate and comment on that obstacle.

Task 04: Search for an accessible path from point A to B.

Task 05: Add an obstacle to contribute to the map.

Task 06: Set up user profile

After tasks completion, they were asked some qualitative and quantitative questions to evaluate their experience with the interface. In particular, they were asked to evaluate difficulty and easiness of the experience that they had during the compilation of each task. The evaluation was based on -3 (min) and +3 (max) range. The quantitative results are reported in Table 3.

As shown in Table 3, although evaluating and commenting obstacles task was found as the most important part of the app, this task was found difficult to accomplish due to its mono-coloured structure. They suggested that it would be better to have a colour coding for the severity of the obstacle (e.g., green, yellow, red), rather than having a scale based valuation system (difficulty 1, 2, 3, etc.). On the other hand, while adding obstacles they had some problems with the navigation from one page to other. They found the interaction sequences too long to follow. Another important comment was about the icons:

Table 3. Tasks and user evaluation

Tasks	Average Evaluation Scale: (Difficult -3 -2 -1 0 1 2 3 Easy)
<i>Task 01</i>	3
<i>Task 02</i>	2,6
<i>Task 03</i>	1,8
<i>Task 04</i>	2,6
<i>Task 05</i>	2
<i>Task 06</i>	2,8

the user-test with manual wheelchair users was done outside in order to simulate a real life experience and the designed icons couldn't be easily seen in an outdoor setting due to reflections on the screen.

Both groups mentioned that they preferred to have the main menu always on the screen to understand in which page they are at the moment. They stated that they found the interface as comprehensible that they could easily understand the icons and their meanings. Participants with the electric wheelchair did not have any particular problems with interaction with the app through their joysticks. The application design will be further developed based on the outcomes of the user test in order to answer the user needs in an efficient way. The next step will be a user test in a real life environment; in doing that many other aspects, such as user emotional state, environment of use, and social setting, will be integrated into the user experience.

CONCLUSION AND FUTURE WORK

In this chapter we have described the methods and techniques adopted in the MEP project to build accessibility maps, i.e., maps with accessible routes enriched with other accessible/non-accessible elements like transport, parking places, barriers, and so on. This multidisciplinary project involves different competences, ranging from computer science, to geomatics and design, and covers different aspects.

MEP is based on the collection of data implicitly obtained through mobile devices carried by interested people when they move around the city, on the automatic reconstruction of the travelled path by means of sensor fusion techniques, and GNSS correction techniques. These techniques improve the accuracy of the resulting paths that can be obtained from sensors of common low-cost mobile devices and advance current state of the art. The user interface offered to the final users has been designed with a user centred-design approach to validate the proposed application with respect to important features like, for example, usability and accessibility.

Ongoing research aims at correcting for severe errors in the GNSS data from the contribution of several MEP-Traces users traveling the same route; indeed, different trajectories collected over time could serve to detect outliers and to correct for GNSS errors in estimating a proper accessible path. As future work we also plan to carry out larger test campaigns in cooperation with external parties, associations and schools and to organize initiatives aimed at finding innovative urban solutions to obstacles detected by MEP. Finally, we plan to extend our applications and tools to all the disabilities.

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KEY TERMS AND DEFINITIONS

Accessibility: Refers to the design of products, devices, services, or environments for people with disabilities.

GNSS: The Global Navigation Satellite System is a satellite navigation system with global coverage. It refers to a constellation of satellites providing signals from space transmitting positioning and timing data.

GPS: Global Positioning System (GPS) is a GNSS system created and maintained by the United States government.

Permanent Station: GNSS reference stations with precisely known coordinates.

Sensor Fusion: Is the combination of sensory data or data derived from disparate sources such that the resulting information has less uncertainty than the one that would be obtained when these sources were used individually.

Standard Point Positioning (SPP): Is a GNSS positioning method to calculate the position using a single GNSS receiver.

Usability: Is the extent to which a product (such as a device, service, or environment) can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use.

User-Centered Design (UCD): Is a framework of processes where the needs, wants, and limitations of end users of a product, service or process are given extensive attention at each stage of the design process.

Chapter 6

Anonymous Pico-Payments for Internet of Things

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ABSTRACT

In this Chapter a new way of payments for Internet of Things services is proposed, based on a stream of anonymous pico-payments realized by means of pico-coins. System architecture and information flow are presented, showing fully automated way of contextual payments which protect customers' privacy. With the proposed stream of pico-payments, two basic problems of efficient and widely acceptable payment method for the Internet of Things are solved: privacy protection, and toleration of frequent unexpected disconnections.

INTRODUCTION

Recently we observe continuously expanding expectations concerning Internet of Things (IoT) (Atzori, Iera, & Morabito, 2010). People are looking for Marc Weiser's predictions come true: computers are smaller and smarter, freeing people from some tedious tasks and acting as "good servants" – unseen, however useful (Weiser 1991). In other words, people expect better integration of real and digital worlds which together constitute smart environments. Smart environments are particularly important in cities where human population is dense. Smart environments are able to automatically personalize services, both real and digital, to improve human life at a lower energy expenditure and lower pollution. However, a question arises how far we are from mass application of IoT devices and which are major obstacles to mass deployment of IoT services?

Up to date, research on Internet of Things (Haller, Karnouskos, & Schroth, 2009) and Services (Towards the Internet of Services, 2015) has been strongly focused on technological issues, such as standardization, identification, communication, knowledge representation and information exchange, as well as human-to-machine interfacing. There are many different solutions to those problems which may

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be successfully deployed. Problems which remain to be solved are ones of economic nature, limiting mass deployment of IoT. As any technical solution, also IoT needs a proper business model. IoT must generate income and profit necessary to cover costs of investment, maintenance and operation. So far, this part of discussion on IoT was bypassed mostly because economic issues of IoT cannot be solved without a development of new technologies going beyond current solutions.

The fundamental problem of IoT economy concerns payment methods appropriate for IoT operation. In the Internet of People (and in the real world as well) payment instruments, such as cash, checks, credit cards and money transfers are always initiated and controlled by human payers (Karnouskos 2004). For several reasons, it is not possible to apply this mode of operation to IoT devices and services. As each IoT device works according to Marc Weiser's "good servant" rule, it is not possible to: (1) foresee the moment and place of a "meeting" of a human with an IoT device deployed in a smart environment, which is providing a service to this human; (2) estimate in advance the duration of such meeting; and (3) control IoT device operation by a human being served. As a result, classical payment methods based on the prior knowledge of the goal, place, and time of the payment, become useless. For example, it is not possible to pay with a credit card to each IoT device a human is passing by in a smart environment, which moreover usually is hidden, to enter a coin, confirm a bank transfer, etc. Moreover, a payment method for IoT should preserve anonymity of payers to protect their privacy, because fear of mass surveillance of IoT users is one of the major obstacles to IoT deployment.

In this Chapter we propose a new payment method basing on a stream of digital pico-coins sent from an anonymous IoT service recipient to an IoT service provider as long as the duration of an IoT service provided. The general concept of this payment method is the following. If an anonymous person appears for a while within a range of an IoT device deployed in a smart environment, her personal electronic device starts to pay for service by sending digital pico-coins with constant frequency as long as that person remains within the range of that device. Detailed description of this method is presented in the third section of the Chapter. Before, in the second section, we describe current methods of payments and we analyze their usefulness for Internet of Things. In the fourth section we present overall system architecture based on streams of pico-payments, followed by the most important technical details related with information flow among key system elements: the city, pico-coin issuer, service providers, and customers. We also analyze possible privacy threats, and finally we conclude the Chapter, showing possible directions for future research.

Analysis of Current Methods of Payment from the IoT Viewpoint

There are a number of reasons why current payment methods developed for people not devices are inappropriate to IoT.

Most of payment methods being in use are based on some material goods. In case of coins, banknotes or checks, pieces of metal or paper are exchanged between payer and a payee. In case of credit cards, though money is immaterial (digital), cards and card readers are material. In case of a bank transfer, again money is immaterial, but a terminal (a computer or a smartphone) is material. In all those methods, a payment is always initiated and controlled by a human payer who explicitly decides when, to whom and how much money is paid.

In case of IoT, where according to Weiser's rule devices should be unseen servants, a payment transaction should arise between devices without direct intervention of a human. Otherwise, an IoT device

will be not unseen by a human who is, however, served. Also, IoT devices which are tiny, cannot receive any material money, and cannot be equipped in large appliance like card readers.

A payment method which may be an inspiration for IoT is direct debit. In this case, a recipient of a repeatable service (e.g., electric energy) paid in a repeatable manner (e.g., once per month) give explicitly right to the service provider to directly debit her bank account without her intervention. She is protected from abuse, because during say ten days she can revoke paid money by one click. However, this method cannot be applied to IoT as it is, for several reasons. First, transactions in IoT are mainly incidental and not repeatable. Second, in a larger smart environment like smart city there may be hundreds of different IoT service providers with whom it would be necessary to sign independent contracts. Third, simple IoT services (like switch on/off a lamp) will cost below one cent which is not enough for a bank transfer. Finally, this method does not preserve anonymity of the payer.

Another payment method which may be an inspiration for IoT are micropayments devoted to the “pay-per-use” business model. This method was originally developed for portals with paid content. For an access to a unit of a paid content (e.g., an article), a portal user agreed to pay a small amount of money, usually a few cents, called a micropayment (Boddupalli, Al-Bin-Ali, Davies et al., 2003). As a single micropayment (Rivest & Shamir, 1997) is too small to be an object of a bank transfer, all the micropayments of a single user who used the portal frequently, were aggregated. At the end of each month a single transaction was issued to pay the aggregated amount of money at once. This method cannot be applied to IoT as it is, for the same reasons as above, except small amount of money for an IoT service. However, aggregation of micropayments of a single user is irreconcilable with anonymity (Roberts 2013). Moreover, such aggregation usually concerns a pair of well-defined operator and a customer, thus it is justified only in the case the micro-transactions are frequently repeated in the scope of the same pair operator-customer. For incidental interactions with IoT devices it is not true, moreover, it is very probably that the aggregated value would never exceed certain level to justify the settlement.

Finally, yet another inspiration for IoT payment method may be digital cash (Eslami & Talebi, 2011). A banknote is a particular sheet of paper and a coin is a particular piece of metal which represent value and may be exchanged for goods or services. The idea of digital cash consists of a particular file that represents value instead of paper or metal (Chao-Wen, & Chin-Chen, 2006). To distinguish such a file (digital coin) from any other files, encryption is used. There is a number of encryption techniques used to create digital cash. The general idea, based on the Public Key Infrastructure (Adams & Lloyd, 2003), is the following. A person asks her bank for a number of digital coins to be stored in her digital wallet. The bank withdraws required amount of money from her bank account and generates equivalent digital coins. A digital coin is a file containing a unique coin identifier digitally signed by the bank with its private key, according to the Public Key Infrastructure. The bank keeps a list of generated coin identifiers. If a bank customer pays with a digital coin, the payee (directly or indirectly) returns this coin to the issuing bank. The bank recognizes its digital signature and deposit equivalent amount of money to the payee account or transfer money to her bank. To avoid double spending, each digital coin is of single use, i.e., after spending and returning to the issuing bank, it is cancelled (inserted to the list of already spent digital coins). The above schema does not prevent from traceability of digital coins. Indeed, a bank may associate a person who required generation of a (unique) digital coin with the person who returns this coin to the bank. In more developed schemas, non-traceability of digital coins is preserved. To achieve this property, a blinding factor is used during digital coin generation (Chaum 1983). As a result, issuing bank blindly signs coin identifier. Bank is able to recognize its signature when the coin is returned, but does not know to whom gave this coin. Thus, bank is unable to associate a payer with a

payee. This case is similar to the use of the traditional cash— the transaction preserves anonymity of the payer, as well as the payee if needed, keeping the level of mutual trust reasonable. Note that such anonymity is still needed for everyday transactions, moreover, its importance seems to be increasing once more and more people realize the fact of traceability of their banking cards – not only by the banks, but also shops, lending companies, etc.

Theoretically, IoT services may be provided for flat rate subscription to a smart environment or from public money. From the business and development perspectives, it is, however, much better to pay for a particular service than for the whole environment. Payment for distinguishable services fosters innovativeness due to the competition of different providers. In case of covering costs of IoT from public money, IoT success will be followed by tax increase which will be hard to accept by tax payers. Also from the point of view of a customer, in many cases it is justified to distinguish the payment for a service in the pay-per-use and the flat-rate manner. For example, some people tend to buy a monthly ticket for a public transportation, expecting everyday ride, while some tend to pay per single route, as they plan to use the bus/tram only occasionally.

From the technical point of view, a service purchase transaction is composed of service provision (by a payee) exchanged for money transfer (by a payer). Usually, money transfer precedes service provision, especially if a payer wants to remain anonymous. A transaction must be performed as the whole. The payee must be ensured to receive the payment, while the payer expects service provision. Any interruption of a transaction results in a fraud, does not matter the reason of this interruption. To explain problems with payment in IoT consider the following analogy. Two persons are interacting, a passenger being in a train, and a food seller being on the platform. When the seller gave a sandwich to the passenger through the window, he liked to pay, but the train moved, so he was unable to transfer money. Under condition that he got a business card of the seller with his bank account number before the sandwich, he could later transfer money for the sandwich, however, losing his anonymity.

In case of IoT, the incidental nature of an interaction with unpredictable moments of beginning and ending, described above, is typical. Imagine an air-conditioning device connected to IoT. A customer is ready to pay in a transparent way (without human intervention) for air-conditioning, however, only while staying near the air-conditioning device. She cannot pay in advance, because she does not know how long she will stay near this device. However, when she incidentally leaves the device operating area and is ready to pay for air-conditioning service, she cannot transfer money to the device because the connection with this device is broken. If she wants remain anonymous, any postponed or aggregated settlement is not possible, because she will never be re-identified as the same person even if she approaches the same device.

To conclude, for IoT we need a payment method adapted to incidental nature of IoT services, which may be used in device-to-device transactions, which concerns very small amounts of money, which may be applied to many different IoT service providers, which is resistant to sudden disconnections and fragile communication, and which preserves anonymity of payers.

Pico-Payments for IoT

To solve the problem of payment in IoT, we propose to replace a single payment due to a service into a corresponding stream of pico-payments of a standard amount of money, say 0.01 cent, called pico-coins. Pico-coins are encrypted files following the principles of digital cash described in the previous section. A pico-payment may be related with arbitrarily chosen measurement units, such as time (a second, a

few seconds, a minute, etc.), amount of information transferred (a byte or its multiplication), occupancy of a radio channel, etc. A scenario we consider in this Chapter is the following. A person converts a given amount of money into pico-coins and stores them in her personal electronic device or in the cloud accessible via her personal electronic device. When such person approaches to an arbitrary IoT device and indirectly accepts its service, her personal electronic device starts to send a stream of pico-coins to that device. This stream stops when the person leaves the range of the IoT device and stops receiving the service. All the pico-coins collected by the IoT device are later converted to bank deposit by the device owner.

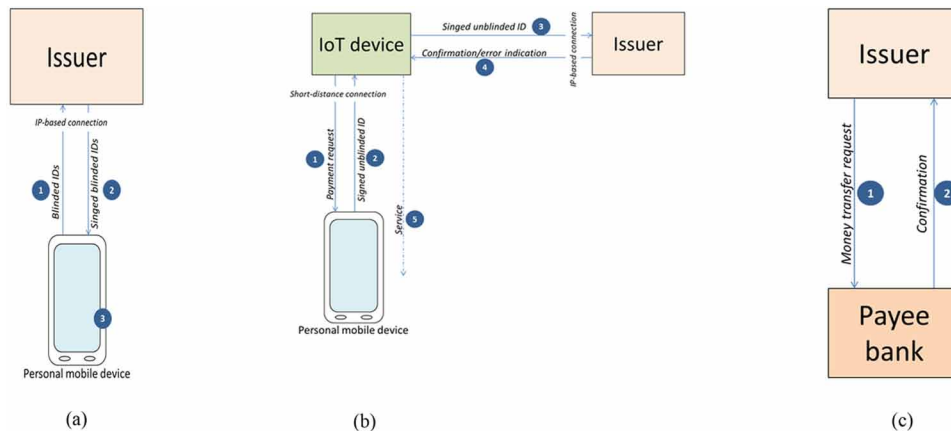
Pico-coins are transferred from the personal electronic device of a service recipient and the IoT device by means of any anonymous, peer-to-peer, short-distance communication channel, such as Bluetooth or Near Field Communication (NFC).

Proposed System Architecture

System architecture is depicted in Figure 1. The schema of generating the pico-coins is presented in Figure 1a. The issuer is a trusted third-party institution, such as a bank. The customer is generating a set of blindly encrypted identifiers of pico-coins, according to Chaum's signing schema. The set is transferred to the issuer using stable and trusted Internet connection (1). Issuer blindly digitally signs identifiers and sends them back to the customer's personal electronic device (2). Inside the device, the blinding factor is removed, unfolding real identifiers of the pico-coins to be stored in device memory for future use (3).

Figure 1b presents the way of using the pico-coins. We assume that there is a short-distance communication channel between the customer's mobile device and an IoT device serving this customer, such as Bluetooth or NFC. For each interaction period, an IoT device to be paid requests a single pico-coin from the customer's mobile device (1). The mobile device gets the next available pico-coin from the repository and transfers it to the IoT device (2). There, the digital signature of the pico-coin is decrypted using public key of the issuer. If the decryption is successful, the payee registers the pico-coin in issuer's server (3) as spent and allows the interaction for the next settlement period. At the same time, the issuer checks if the just-received pico-coin was never used before. If so, the pico-payment is cancelled with

Figure 1. (a) generation and registration of pico-coins, (b) usage of pico-coins, (c) periodic, aggregated money transfer



appropriate message sent to the payee device to detect a fraud and immediately stop the service (4). Otherwise, a confirmation is sent (4), service is continued (5), and, once this period (e.g., a second) is over, the operation is repeated and the next pico-coin is transferred and verified.

To pay an IoT device for a service, the customer personal electronic device does not need an Internet connection. So, from the point of view of its owner, pico-payment is settled off-line. Surely, one must generate and register appropriate number of pico-coins inside the device, but this task is not limited by nowadays mobile devices and amounts of their memory, thus may be done say once a month after a warning generated by the device. However, Internet connection of a serving IoT device is a must (which is a basic feature of any IoT device anyway).

Note that an interaction may be broken at any moment with no consequences to both the payer and the payee. In such case, once a request is generated but not acknowledged by the next pico-coin, the service is over. Note also that several streams of pico-coins may interact with the same IoT device at the same place and time – these streams are not seen by the IoT device as separated ones, but rather as a single stream (anonymous).

After certain period of time, e.g., once a day, the payee requests (Figure 1c) a macro-settlement of all pico-transactions from the issuer (1). Then, the issuer aggregates all the pico-coins registered, and transfers corresponding amount of money to the bank account of the owner of the IoT device with appropriate confirmation message (2).

Pico-Payment Settlement Strategy

As mentioned in the previous section, settlement period depends on an IoT device and a service provided – this is the device that periodically requests pico-coins. Thus, it is up to the owner (operator) of the device to choose a natural unit related with each pico-coin – this may be a second/minute of service provision, certain amount of data transferred (MB, GB), percentage occupation of a communication channel (radio bandwidth), etc. This is an IoT device that decides about frequency of payment requests: higher frequency, higher cost of service. Cost of service may be easily differentiated according to the context. For example, for a parking place during the rush hours the requests are generated every second, while during the night – every minute, setting the service much cheaper in the latter case.

It is not reasonable to assume that all customers will unconditionally accept all (paid) IoT services. Thus, there is a need for service assessment, i.e., to decide if this service is worth paying. Returning to Weiser's rules, a human cannot decide whether to accept an offer of any just-passed-by IoT device or not – such activity would be in contradiction with the principle of an IoT device being an unseen servant. Instead, the decision of service acceptance or rejection must be taken by user's personal electronic device automatically, based on some general preferences registered by the user. It is not reasonable to relate such decision with every single IoT service. Instead, all the possible services must be categorized, and the user preferences must deal with certain categories. For example, a user may agree to pay for public transportation services and car parking places, however, she refuses to pay for incidental air-conditioning at public places.

Similarly, to the payment, also service classification must be trusted by the customers to avoid abuses. Thus, a trusted third-party has to be applied for service categorization and assessment. To clarify further discussion, we assume that this is a task of a smart city ("city" for short), acting as an issuer of certificates of service categories.

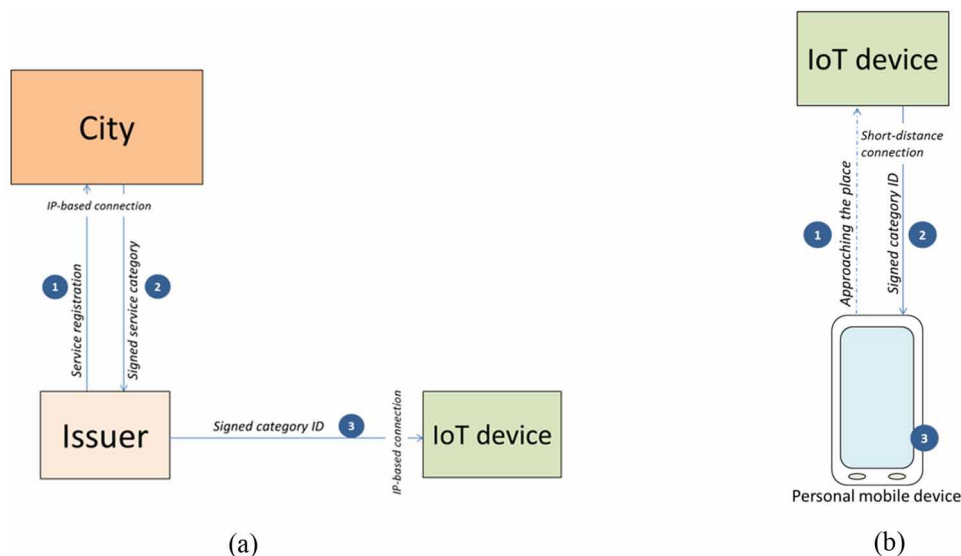
The detailed strategy of trusted service categorization is the following (Figure 2). A service provider (owner of an IoT device) presents service description (Figure 2a) to the city (1), and proposes certain service category. If the city agrees, after its internal process of assessment, a digitally signed service certificate is sent (2), to be in turn transferred and stored in the IoT device (3). The certificate contains both service identifier and service category. Showing the certificate, a device may prove it provides a service of a certain category.

Once a customer approaches an IoT device (Figure 2b), first (1) her personal electronic device receives the certificate of service category provided by that device (2). If the category fits the user preferences (3), the service is accepted and further paid by the stream of pico-coins. Otherwise, the interaction stops with no consequences.

Note that the whole verification of service category may be performed off-line, i.e., without accessing the Internet. Note also that device owner/operator may remain anonymous for the customers. Even if all the details about the service and its owner are known by the city (Figure 2a), at the verification phase (Figure 2b) only the information from service certificate is transferred to the customers. Usually, service certificates do not provide details about service operators – service categorization is enough to assess a service by a customer. Similarly, the city collects no information about the usage of a given service – the details about usage and payments for this service are known only by the device owner.

We did not take into account the situation when an unfair operator offers a certified service under non-certified conditions. For example, the service “ticket for the tram route” to be offered inside the tram, will be asked on the street at the tram stop. Such fraud will be detected sooner or later by the customers, and the unfair service provider will be eliminated from the market, starting from withdrawing the service certificate by the city. A possibility of some frauds always exists. The role of service providers and their supervisors is to monitor services, detect frauds, and protect customers by technical and managerial means as well as by informing and educating them. Such approach is used by e-banking service providers. A similar problem arises when it is difficult to determine if a customer is at a given moment

Figure 2. (a) classification and registration of a service, (b) trusted service categorization



within the range of the service or not. Imagine air-conditioning in a given room. Once a person enters this room, she must pay for the usage of the device. The device detects the person by the availability of her mobile device, RFID tag, etc. It is possible that the detection will be done at a larger distance, e.g., while the person is in the next room or in the corridor. Such errors must be eliminated either at the operator side (by e.g., restricting radio range of the transmitter), or by a verification at customer's device (by e.g., double-checking of the distance and location of the serving device). In this paper, due to the lack of space, we are not able to broaden this discussion, assuming that such mistakes are eliminated by proper implementation of the system.

Privacy Protection

Pico-payments proposed in this Chapter solve the problem of privacy protection in the IoT. People are more and more conscious of importance of privacy protection, so they are not willing to provide information about their finances and activities to service providers. If the blind digital signature is used to generate pico-coins, and anonymous or pseudonymous communication with personal electronic devices is assured, IoT service providers, IoT financial intermediary, banks and other involved parties are unable to associate a customer with an IoT service. As all pico-coins have the same value, and may be used anywhere and in any order, observing the stream of pico-coins one cannot deduct any information about the whole macro-transaction, i.e., an interaction of a human and a device of a certain duration, at a given place and time. Moreover, as different streams of pico-coins are mixed while many users interact with the same device, one is unable even to determine the total value of a macro-transaction.

While analyzing privacy, key issue is “who exactly knows what?” There are four parties in the proposed system: city, which task is to categorize services, pico-coin issuer, service providers (payees) and customers (payers). Below, we explain which information they possess and for what purposes.

The city knows all the services of all the service providers, as well as a category of each service, because all the services are objects of assessment and certification. However, city has no information how a given service is used – is it popular or not, what profit it generates, where the service is offered (geo-location) and for whom, and even is it available or not. The city also has no information about the number of service customers.

The pico-coin issuer knows the customers and the number of pico-coins each of them requested. However, this party has no knowledge how and when the pico-coins are spent. The issuer has also no information about the services. The issuer knows only the total income of a single service provider (aggregated income for all the services of this provider).

A service provider knows the number of pico-coins received in exchange of each service that is under control of this provider, as well as total aggregated income for this service. However, the set of pico-coins cannot be parted among particular customers. The provider has no knowledge how many customers received the service during certain period of time – what is known is only total service provision (number of pico-coins paid for this service in a given period of time). So, the provider is partially able to assess the popularity of a service, however, having no knowledge if this popularity is caused by a large number of customers using the service in a light manner, or a few customers using the service heavily.

A customer is able to assess the usefulness of a certain service, based on the service category, and let his personal electronic device decide in real-time whether to use/pay for this service or not. The customer has no information if this service is/was in use by any other customer, and what is its popularity. Moreover,

details about service provider (such as real address, phone number, etc.) may be hidden for him – the customer possesses only the information that is intentionally stored in service certificate. Anyway, the customer trusts the service as long as he trusts the city that digitally signed the service certificate. The customer knows the exact number of pico-coins spent for each service, its duration, time and place. As a consequence, only the customer is able to compute total amount of money spent for this service during a given period of time, e.g., a month. Based on this information, private application of this customer may generate some alerts, restrict the usage of some too expensive services, etc.

In the above discussion it was assumed that there is no conspiracy, and two or more parties are not working together against any other party. However, if such connivance occurs, privacy may be endangered. Privacy threats in such cases are discussed below.

If the city and the pico-coin issuer cooperate, then these parties may join the information about the services and total incomes of given service providers. Then, it is possible to violate privacy of a service provider; however, still the customers of the services are protected. From the market point of view, this threat is serious; however, not very probable – any publicly available information about such fraud co-operation would question credibility of both the city and the pico-coin issuer. This is not in their interest as trust is in the core of their activities.

If the pico-coin issuer and a given service provider cooperate, there is no additional business advantage for a service provider. The issuer would then know the profits for each service, however, still having no detailed information about the customers. Thus, this case is only hypothetical.

Similarly, if the city and a given service provider cooperate, the city would know the profits for the services of this service provider and no information about the customers.

In the latter two cases we may assume asymmetric agreement – the issuer/city collects the information from a given service provider, in turn providing similar information about all the other, competitive providers and services. This case would be soon detected and punished, thus we should treat it as impractical. Anyway, the information about the usage of certain services by certain customers is still inaccessible for such consortium.

Finally, if all the basic parties except the customers would agree to exchange the information, still there is no way to violate customers' privacy and deduct some knowledge about service usage by particular customers.

Last but not least, note that even if anonymous payments are the base of the system, money laundering is restricted. This is due to the fact the pico-coin issuers take full control on number of the pico-coins issued, as well as full registry of the persons who bought them. This mechanism is similar to the usage of nowadays metal coins – even if they are used anonymously, nobody is claiming this is a possible way of money laundering, and in any case the police may ask for details both the issuer and the customer.

As follows from the above discussion, in any case the privacy of a customer is protected. What is at risk is the case of possible fraud consortium of two or more parties, which is unlikely on nowadays market.

Note that the goal of the approach proposed in this paper is to prevent payment tracing, neither from the point of view of an operator, nor the city, coin issuer (a bank), etc. This is similar to nowadays coin-based payments – who complains that coins are not traceable? This is just a different payment schema, to be used in parallel with traceable ones – as needed.

Automatic Payment

Breaking a classical transaction into a stream of pico-payments requires much greater level of automation. As a person cannot authorize each pico-payment separately, a financial autonomy of her personal electronic device (being the representative of that person towards IoT devices and services) is required. This is a personal electronic device task to accept or not an instantaneously offered IoT service and if so, to initiate a stream of pico-payments. Such decision is based on a match between trusted service category and user preferences. Decisions of a personal electronic device followed by financial consequences have to be restricted by some limits imposed by the customer, which may be daily and/or monthly, different limits to different service categories (such as parking, public communication, air conditioning, etc.). From the technical point of view, a personal electronic device should be able to withdraw customer's money from her bank account. This task may be done automatically or manually. In the first case, similarly to the way people now use sub-accounts for their children, they will arrange sub-accounts for their computers/smartphones/tablets, etc. Such a sub-account, probably restricted as for the operations available and the monthly budget, would be periodically used to buy pico-coins.

In the second case, the personal application would ask its owner to buy some more pico-coins once the wallet is almost empty. Then, the humans would take the decision how many pico-coins buy at once. Though this operation somehow breaks Weiser's rule about unmanageability of IoT services, the choice should be left to each individual consumer.

Although automatic payments are not the new idea (Bohn, 2005), in this area we still observe more questions than answers and practical, real-life applicable proposals. We perfectly know that there is no a single solution to all the problems related with payments. We propose a technology able to solve payment problems in some important application scenarios directly related with IoT. This technology has to be complemented by countering threats including those mentioned in the Bohn's paper: bad decisions of the computers that agree to pay for something that is not really needed by particular humans, a need for fair justification of the usefulness of the paid services, etc. Solutions will be combined: technical, managerial and informational ones, as in classical payment systems.

Contextual Payments

Automation in turn requires much greater care about the context. For example, an automated car should automatically pay for the parking place only under condition the car owner is driving this car. Broadening this idea to more IoT services, we should extend the account information about some contextual rules, mostly user-defined, to fit to individual requirements and expectations. One may expect that such control will raise the level of societal acceptance of automated payments, which is the last key for the success of IoT. However, broadened discussion about the context is beyond the scope of this Chapter and needs more research.

Note that for the context analysis we tacitly assume the presence of a personal electronic device at a given location also means the presence and responsibility for the financial decisions of its owner. So, in this analysis we bypass such treats as device theft, or unauthorized use of personal applications. There are, however, several mechanisms and customs to limit this threat to the maximum extent, such as password-protection enabling operation (e.g., once a day), bio-metric sensors being able to recognize automatically device owner, etc. Anyway, the abuse is possible only to the moment the pico-coins stored

in the personal wallet are not over. Limiting the number of the pico-coins stored in the personal electronic device, one may also restrict the threat to the reasonable level.

FUTURE RESEARCH DIRECTIONS

The anonymous pico-payment system proposed in this Chapter should be seen as the begin of a new trend in realization of financial tasks in IoT, taking into account specifics and growing possibilities of nowadays hardware and software, especially personal electronic devices. Even if the technical problems related with the proposed payment system are solved, there are a number of organizational and social aspects that still should be discussed. We may enumerate such problems as group-based services (i.e., services for a group of people rather than a single customer, thus forcing the cooperation among anonymous customers followed by shared payment (Wójtowicz & Wilusz, 2015)), good assessment of service categorization (probably an extensive ontology to deal with fuzzy service descriptions and customers' expectations), and direct competition of service providers with similar service offers in the same place/time (a need for automatic selection of the individually "best" offer for a given context). Future research should be also devoted to a general architecture of a smart city (Chourabi, Nam, Walker et al., 2012) offering a possibility to provide both paid and free services, and different, intermixed business models, including properly adapted classical models such as pay-by-advertisement, pay-by-personal-information, etc.

CONCLUSION

Internet of Things will be widely accepted only if people will not have feeling that they lose control of their life due to unwanted over-automation in their surroundings and mass surveillance. Payment is the biggest challenge, as it is the most universal service which conditions investment in IoT, its operation and maintenance. The method of payment for Internet of Things services proposed in this Chapter, based on a stream of anonymous pico-payments realized by means of pico-coins, solves two basic problems of efficient and widely acceptable payment method for the Internet of Things: privacy protection, and tolerance for frequent unexpected disconnections. The next step of research will be a pilot of proposed technology that will permit to study customer reaction. As the proposed technology is significantly different from the classical electronic payment systems, it will be necessary to study how to convince different kinds of people to use it.

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KEY TERMS AND DEFINITIONS

Internet of Things: A proposed development of the Internet in which real-world objects have network connectivity and data-processing unit, allowing them to send, receive, and process data.

Personal Electronic Device: A mobile device (also known as cellphone device, handheld device, handheld computer, palmtop or simply handheld) being a pocket-sized computing device, typically having a display screen with touch input or a miniature keyboard.

Pico-Coin: A unit of payment of certain fixed value, responsible for a settlement of a single pico-payment transaction.

Pico-Payment: A payment characterized by very low amount of money (small fraction of a cent), not to be realized with nowadays financial instruments and monetary units.

Section 2

Enriching Urban Spaces

Chapter 7

Co-Producing Tools for Participation and Action in Urban Environments

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ABSTRACT

The chapter addresses the potential of co-production in relation to enhancing the participation of a city's inhabitants in its design, management and use. It does this by discussing a co-design process, which explored how participation might be extended to the design of digital platforms that could allow city inhabitants to be involved in the identification of needs, goals and actions for their everyday environments. The chapter outlines three spatial-technological experiments involved in the co-design process and the resulting web 2.0 platform prototype, which illustrates how collaborative technologies might stimulate collective actions. Acknowledging the importance of creating opportunities and spaces for reflection within technology-enabled participatory processes, the notion of co-production is extended to the iterative and collaborative production of knowledge and actions for the city. In this conceptualization, inhabitants' role shifts from that of 'users' or 'consumers' to active (and reflective) 'co-producers' of a more resilient city together with the decision-makers.

INTRODUCTION

Cities have the capability of providing something for everybody, only because, and only when, they are created by everybody.

Jane Jacobs, The Death and Life of Great American Cities, 1961

'Co-production' and related terms such as 'co-design' have become increasingly prevalent in the vocabulary of policymakers and urban innovators in recent years. Widespread economic difficulties faced by governments and municipalities, together with wider challenges such as environmental degradation, an ageing society and an unreliable global financial system, are prompting the search for alternative ways

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of providing public services. Current services are seen to be badly-equipped to cope with these challenges, particularly as governments cannot continue to rely on continuing economic growth to finance their provision. In this context, ‘co-production’ has been put forward as having the potential to transform public services and make them more effective and cost-efficient by involving users in their design and delivery (Boyle & Harris, 2009).

In parallel, Information and Communication Technology (ICT), collaborative technologies in particular, have become core tools in the development of ways of improving the efficiency of public services, as illustrated for example by the concept of ‘smart cities’ (Caragliu, et al., 2009; Hollands, 2008). However, besides citizen-sensing applications, developments in ICT also offer interesting opportunities for improving knowledge regarding everyday life practices and experiences of local residents, thus potentially informing and enhancing local planning processes. The rapid expansion of social media and web 2.0 applications, in particular, has opened up opportunities for new forms of public participation outside formal face-to-face meetings and consultations, in everyday life situations (Horelli, 2013) and using seemingly mundane technologies. Indeed, it could be argued that these developments in ICT have introduced a paradigmatic shift in relation to civic participation and also the ways in which geographic data are (co)produced. As illustrated by the collaborative OpenStreetMaps project, in which Global Positioning Systems (GPS) technology has been used to trace city maps with the help of inhabitants, it is now difficult to differentiate data ‘producers’ and ‘users’ in an environment where many participants function in both capacities.

These developments in the socio-technological landscape indicate a pressing need to expand the discussion around co-production beyond its potential to find improved solutions to current public service inefficiency – it has become indeed imperative to also address the social, cultural, political and technological dimensions of co-production (Petcou & Petrescu, 2015). Rather than only meeting public demands and needs, how could co-production processes extend to the ways in which a city is developed, managed and used? What kinds of tools might allow city inhabitants to be involved in identifying needs, establishing goals and taking collective action for improving everyday environments? And what kinds of processes might be needed in order to stimulate and sustain such actions?

This chapter aims to address some of these questions. It does this by discussing an experimental study, which explored possibilities for co-designing a collaborative platform that could be used in urban planning¹. The study consisted of three spatial-technological experiments (i.e. combining physical presence in urban space with the use of digital technology) and was carried out in Dublin, Ireland. Its outcome was a prototype collaborative digital platform, which offers opportunities for sharing everyday life experiences of, and in, urban space, and creates an arena where ordinary inhabitants and city decision-makers can come together to discuss and envision possibilities for the future development of these spaces. After situating the research in its wider theoretical context, the chapter will focus on two main aspects of this experimental study: first, it will discuss how the participants contributed to the design of the digital platform – the co-design process; and second, how the platform, which emerged through carrying out the co-design process, might stimulate collective actions in everyday urban environments.

Background

The term ‘co-production’ is not new. It emerged in the social sciences more than four decades ago and was originally coined in the late 1970s by political economist Elinor Ostrom and her team at Indiana

University, who were trying to explain the growing rate, at the time, of neighbourhood crime in Chicago. Recognizing that services (in their case, policing) rely not only on the expertise of professional providers but also upon the knowledge and lived experience of service ‘users’, Ostrom’s team defined co-production as “the process through which inputs used to produce a good or service are contributed by individuals who are not “in” the same organization.” (Ostrom, 1996, p.1073). While the ‘regular’ producer of services such as education or health is usually a government agency, Ostrom acknowledges that all public services could also be potentially produced by those who are typically referred to as the ‘client’. Furthermore, she suggests that while ‘client’ is a passive term, co-production implies that citizens can play an active role in producing services that are important to them.

Co-production has been associated by its recent proponents with a shift in power, responsibility and resources from professionals towards individuals (Boyle & Harris, 2009). It has been suggested that the concept goes beyond ‘citizen engagement’ or ‘service user involvement’, being aimed at fostering equal partnerships between service professionals and users. However, while the active engagement of users who have previously been seen as passive recipients is largely considered positive, the concept has been criticized for potentially being used to cover the withdrawal of services, therefore minimising the accountability of the state by blurring the lines of responsibility for the quality of public services. This critique has been accentuated by the reintroduction of the concept at the time when ‘Big Society’ principles were being proposed by the UK’s Conservative Party (Conservative Party, 2010). The implementation of this policy, which promoted the idea of the public becoming “not the passive recipients of state services, but the active agents of their own lives” (Cameron, 2007), coincided with large-scale cuts in public expenditure programs, aimed at addressing macroeconomic concerns. In view of this, economic reasons have been argued to prevail within practical applications of co-production principles in relation to the provision of public services, while the goal of shifting power relations revolving around services and their production has been marginalised (Petcou & Petrescu, 2015).

At the same time, developments in Information and Communication Technologies (ICT), such as GPS-enabled mobile devices and smartphones, are being put forward as promising tools for improving the efficiency of public services, as illustrated by another concept of recent interest for policymakers, that of ‘smart cities’ (Caragliu, et al., 2009). For example, the aggregate mobility of people (based on their mobile phone usage) when visualised synchronously with the flux of public transport (based on the use of GPS sensors) could give a better understanding, through visualization, of how neighbourhoods are used in the course of the day and how the distribution of buses correlates with densities of people (Calabrese & Ratti, 2007). In turn, this could improve the provision of public transport. Nonetheless, this increased focus on technology and the involvement of large ICT companies, such as Cisco and IBM, in the development of smart city applications has recently given rise to a debate regarding the needs such initiatives are actually aiming to meet. An important question in this debate is whether such developments are concerned with meeting the corporate needs of marketing campaigns (and consequent competition among cities), or whether they aim to bring about the social intelligence needed for cities to really be smart (Allwinkle & Cruickshank, 2011). In this context, it has been argued that such applications are more concerned with economic growth and competitiveness in the global knowledge economy, rather than with a rebalancing of power between the use of information technology by businesses, government, communities and ordinary people who live in cities (Hollands, 2008).

The efficiency of services is of course important for a city to function well. However, it is important to recognise that a city is more than just “hardware” (Sassen, 2011) or efficient services – it is also made up of people’s physical, social, political and emotional interactions with their urban environment. At

the same time, web 2.0 environments, social networking sites (e.g., Facebook, Twitter) and the ‘open source’ digital movement have changed the ways in which people interact and collaborate with each other in the online world, introducing new demands in relation to urban planning and development. As some have argued, cities can also “talk back” (Sassen, 2011) (e.g., react to plans that do not reflect inhabitants’ needs). People tend to develop ways – or “tactics” (de Certeau, 1984) – to adjust the city to their everyday lives when the city does not correspond to their needs. For example, open source technology, which includes aspects such as free access to information, self-organisation, mass collaboration, non-exclusive services and user participation, has opened up possibilities for people to “make the city theirs or urbanize what might be an individual initiative” (Sassen, 2011, no pagination). The concept of ‘open source urbanism’ has emerged in this context. Yet, while ‘open source’ is gradually becoming a notion centred on consumption (i.e. free to use) (Haque, 2007), ‘open source urbanism’ draws on principles such as the collaborative and iterative form of production associated with these technologies and the notion of sharing with others. From this perspective, ICT offers the potential to enhance democratic debates about the kind of city people want to live in and to allow them to collaboratively produce the environments they inhabit (Hollands, 2008).

An Experimental Co-Design Process

Rather than developing and testing a prototype, the study discussed here took a co-design approach to the development of the intended participatory platform – its concept and features emerged from a collaborative process with potential users, represented by the participants to the three experiments included in the study. This co-design approach addresses recent calls for expanding participatory processes in urban planning to collaboration in the actual design of the digital technologies that may be involved in such processes (Saad-Sulonen, 2013). The three spatial-technological experiments involved in the study employed mobility as a ‘conversation starter’ – a starting point for expressing and sharing experiences of the city and everyday urban environments. The experiments varied in terms of their participatory aspects, extent of spatial focus and use of ICT. Their design and sequencing were aimed at making the transition from a researcher-mediated process to one that encouraged interactions among the participants through the use of web 2.0 technologies, with the aim of enhancing their role in the design process.

The first experiment consisted in a hybrid diary study, which combined GPS-tracking, photography and text inputs, and was developed as an individual exercise (i.e. conducted and discussed individually with the participants). The experiment was aimed at obtaining a written and visual image of the participants’ daily interactions with the city through movement, as initial exploratory step in the research process. The participants were asked to trace their movements through the city over a chosen week using a GPS tracking device, to record their experiences in a written diary and to take photographs of any elements of the city that they felt were meaningful in their daily experiences. The study was followed by interviews with the participants about their experience of diary-making. The interviews were conducted individually with each of the participants, using maps as basis for discussion, which showed their own contributions and also collective input. This process encouraged reflection not only on their own journeys, but also on other diarists’ input as expressed in the collective map representations.

The second experiment consisted in a collaborative three-week workshop and was aimed at making the transition between the insights of the diary study and the extended use of online and mobile technologies. The experiment explored ways of gathering and visualising experiential aspects of the city and movement through it, and of representing them in a collective way, mediated in a digital environment.

The workshop was carried out in collaboration with artists and software developers, and the methodology was inspired by participatory planning approaches prototyped in the late 1960s in the United States by Lawrence and Anna Halprin (Halprin & Burns, 1974) and situationist practices (Sadler, 1998). The workshop was therefore designed to contain a series of ‘urban awareness walks’, which were conducted both individually and in groups and ranged from open, exploratory *dérives* to guided, pre-determined routes. Their aim was to encourage direct interaction with space, to enhance an awareness of how a selected city area was being used and to open up opportunities for a better understanding of the local area’s qualities, deficiencies and potential. The outcome of the workshop was a map-based digital prototype, which visualised the participants’ GPS traces, their photographs and comments annotating urban features of interest, encountered and recorded along their walks.

The third and final experiment was conducted as an online study and examined the potential of locative media and collaborative online mapping tools to translate and adapt the previous two studies to a web 2.0 domain, in order to make the transition to a fully digital platform. Similar to the previous experiments, the participants used mobile tools to track their routes through the city; to take photographs; and to make notes about features that were relevant to their daily urban experiences. This time, two existing platforms were employed: first, a trip-recording mobile application (EveryTrail², used also in the previous workshop experiment), which the participants installed on their smartphones; and second, an online mapping platform (Crowdmap³) through which the participants could share their contributions with the group, and visualise individual and collective inputs. The use of these web 2.0 tools was aimed at enhancing the participants’ role in the ICT design process, and also at making the transition towards wider public participation.

The findings of these three spatial-technological experiments had a key role in the design of the platform prototype. For example, the hybrid diary study highlighted important issues regarding inhabitants’ habitual interactions with the city. One finding which was particularly revealing was that the diary-making as a whole (i.e. the diary-making and the reflective interviews) led to many of the participants reporting a heightened awareness of their knowledge and daily use of the city. This heightened awareness effect varied in length; for some participants, it lasted only during the diary week while others reported that it continued for a period after the study. Nonetheless, the experiment reconfirmed that besides concrete, rational factors, such as getting from A to B, people’s movements throughout the city are also affected by experiences embedded in everyday practice, typically difficult to be consciously rationalised or recognized because of their habituality (Spinney, 2010). Diarists’ examples include experiences of noise and the visual effects of street litter, which prompted them to avoid certain areas; or places from which their children could watch trains passing by and which they included as part of their everyday routes. Taking part in the diary study enabled some of these experiences and related aspects of the city to be noted and expressed by the participants.

This heightened awareness process took place ‘on-the-move’ through the lens of the camera, which brought about an increased sensitivity to what was being captured, and also during the reflective interviews by visualising the collective GPS-based maps, which prompted further discussion and reflection. When seeing their individual traces in the context of those of the other diarists, the maps made participants more aware about their own uses and knowledge of the city. They realised that they shared their everyday routes with others and also that the same space may be seen, known and used very differently by different people. For example, one diarist found that he might take the same route every day without properly knowing its resources or amenities; this came to light when another participant who shared the same daily route identified a local park that was previously unknown to the first diarist, even though he

lived nearby (Figure 1). Thus, even if they were conducted individually with the diarists, the map-based discussions suggested the importance of sharing experiences and local knowledge among the participants, and indicated the potential value of expanding the diary-making process to a wider audience, which could generate engagement amongst those taking part.

Drawing on the hybrid diary study, the second experiment – the collaborative workshop – was aimed at enhancing participants' awareness of their surroundings so that they could take better notice of, capture and reflect upon those elements of the environment meaningful to them. This was sought on two levels: individually, by encouraging routes other than the usual and by using prompts that facilitated a different kind of experience (e.g., slower, sensorial); and collectively, by facilitating group discussions on the current and potential uses of spaces identified during the walks. These workshop discussions indicated that although experienced (and reflected upon) individually, the urban awareness walks offered a common basis for discussing the local city area chosen for the workshop and opened up ideas about its potential by encouraging first-hand interactions with urban space.

The workshop experiment led to an initial digital prototype⁴, an online map, which served to visualise the collective contributions of the diarists (i.e. their GPS traces, photographs and notes). One of the features of the digital prototype was the absence of a 'base-map'. Instead, building on the diary study, the city was seen as being 'drawn' by inhabitants' movements (i.e. GPS traces) and 'coloured' according to how each person experienced it, mediated via their photographs and notes about experiences along the walks (Figure 2). Recalling Kevin Lynch's concept of 'city image' (Lynch, 1960), the prototype is conceptualized as a re-drawing of the city based on inhabitants' movement, and it encourages sharing and discussion of individual experiences and local knowledge of the city.

The digital prototype, by providing a space where individually-created maps can be visualised together, indicated the value of sharing movement and city experiences with others – both among ordinary users, and also between them and city decision-makers. On the one hand, this has the potential to enrich and expand individual city images, and open up alternative possibilities regarding routes, travel modes or

Figure 1. Park photographed by one diarist but unknown to another participant who lived nearby (each of the two diarists' routes is represented in a different line colour)

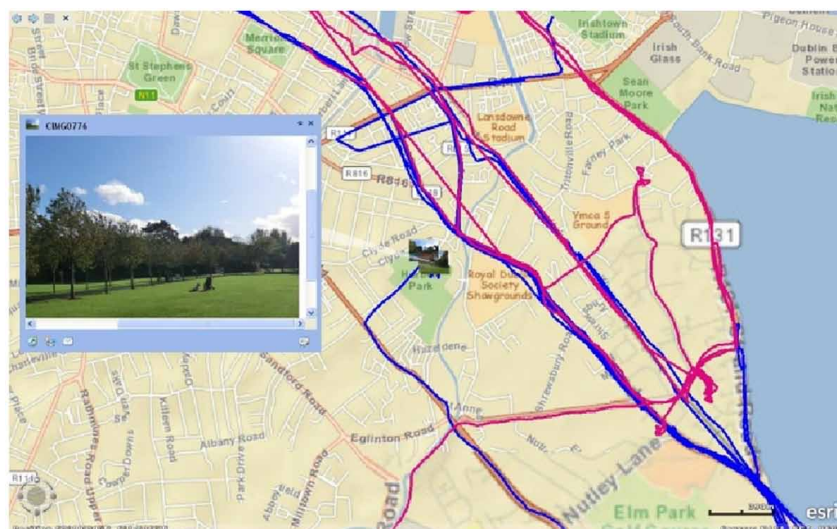
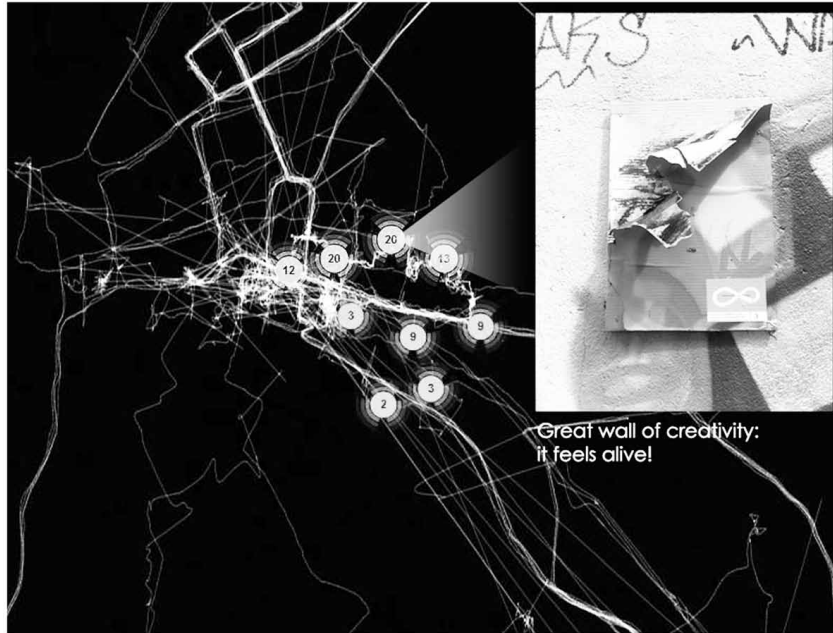


Figure 2. Digital prototype (image based on existing website: <http://electronics.org/infinitycity/>)



available services and facilities. On the other hand, it can make visible routes or places that are important to how inhabitants move about and experience the city, but that may be ‘invisible’ or unknown to city planners. Using a digital platform, such places could be identified by local inhabitants and brought to the attention of the planners.

The third and last experiment took forward some of the digital prototype concepts and explored how it could expand into a tool for engagement. In particular, the experiment focused on the interactive aspects of the platform intended to be developed. The two existing tools used in this experiment indicated the value of merging the communicative and networking aspects of social technology (e.g., Facebook) with the visual aspects of maps. This allows bringing conversations conducted through social media channels in one place, on a map, which makes such conversations locatable and easier to relate to. However, while this experiment was part of the design process for a platform that could be used in planning, feedback from the participants indicated that people might actually be more willing to use such a tool if it was not targeted specifically, or primarily, at urban planning. This concern referred particularly to its potential uses as a data mining platform for commercial interests. Instead, what was seen to motivate people to use it was the possibility of sharing, and finding out about, ‘quirky’ features of routes or places in the city (e.g., unusual building details, ‘secret’ gardens or quiet cycle routes). This could offer a personal interpretation of the city, make one’s habitual journey more interesting and even make it appear shorter when perceived to be too long to walk or cycle. Such features have the potential to break the routine of everyday movement, which emerged in the diary study to prevent experiences embedded in everyday practice to come to the surface and be expressed.

A PROTOTYPE COLLABORATIVE PLATFORM

The co-design process discussed previously resulted in a prototype ICT platform, entitled ‘Urban Spacebook’. Conceptually, the platform can be described as a map-based tool for engagement between ordinary inhabitants and the local planning authority, which merges aspects of social technology (e.g., Facebook) with visual representations of movement and city experiences (e.g., GPS-based maps). The concept employs mobility as a way of initiating conversations in, and about, urban space and GPS technology as a tool that can facilitate a re-mapping of the city from the perspective of its inhabitants. Furthermore, the platform aims to provide a positive space that can facilitate inhabitants’ proactive and ongoing engagement in the development of their everyday urban environments. It offers opportunities for eliciting and making ‘visible’ experiences of such everyday environments by employing current pervasive technologies (e.g., locative media and collaborative online mapping) and by encouraging reflection on habitual interactions with the city through movement.

Technologically, the prototype is envisaged as an open source web 2.0 platform – essentially a map-based website and a mobile application – for geo-tagged user-generated content, with a focus on inhabitants’ movement through the city. Users can share their experiences of the city and everyday movement, and connect with others through interactive maps that include photos and notes (e.g., text, sound recordings) plotted along GPS traces of routes.

The mobile application allows data logging on-the-move (e.g., route tracking, photo sharing) and the provision of location-related information (e.g., alternative routes or points of interest triggered by geo-location). Drawing on the second experiment (the workshop) the location-aware feature is aimed at encouraging the user to take a detour from his/her usual routes or ways of experiencing them, and discover what others may have shared (Figure 3). As suggested by some of the participants in the co-design process, this may include ‘quirky’ features, local uses or activities that may be found in the area. This can offer an augmented experience of the city, which can break the routine of everyday movements and allow users to notice features of routes usually taken for granted, as discussed in the hybrid diary study.

Moreover, looking at everyday spaces with the eye of a tourist (or from the perspective of local residents) can enhance one’s awareness of the environments people inhabit and their familiarity with such places (Gordon & Silva, 2011). By becoming more aware of their environments through first-hand

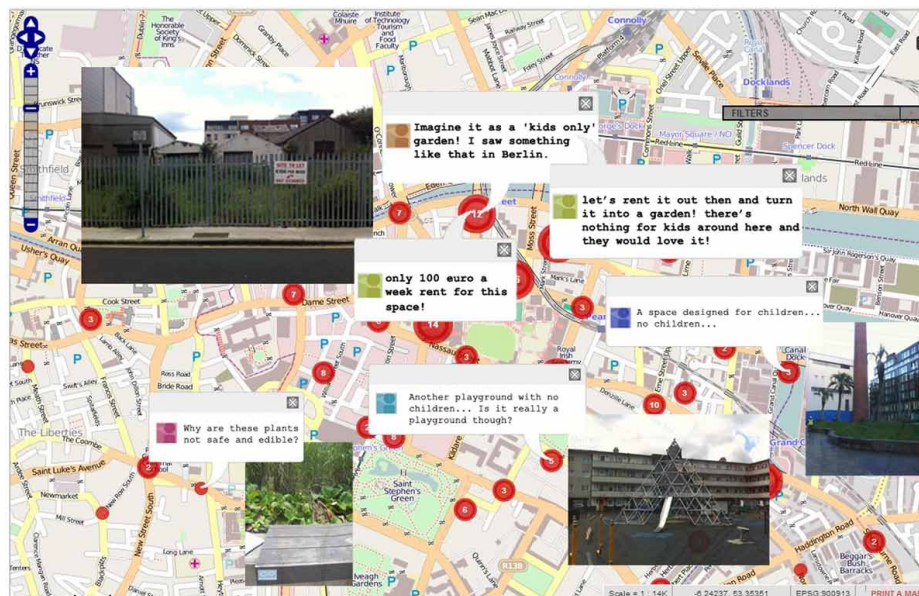
Figure 3. Location-based suggestions of alternative routes and/or places of interest



experiences, users can better define existing issues and suggest relevant improvements – for example, through the use of geo-tagged photographs and comments. Furthermore, increased familiarity with, and attachment to, places in the city can motivate efforts to improve them and enhance participation in related planning processes (Manzo & Perkins, 2006). Rather than promoting ‘negative objecting’, which is one of the main limitations to public participation in planning (McGuirk, 1995), the mobile app can enable a proactive role for those who use it. The possibility of proactive engagement was an important feature for the planners with whom the prototype was discussed⁵, as it could contribute to a more positive and collaborative relationship between them and city inhabitants.

Complementing the mobile app features, the map-based website offers a space for collective discussion and reflects the collaborative aspect of the platform. It facilitates collective data visualisations (e.g., multiple data layers that are perceived at a glance), and interaction and communication among users. Besides making visible shared routes (and potentially different types of local knowledge regarding them), the visual and interactive aspects of the digital map can bring to light shared concerns or ideas, and connect users that might not have been able to meet or enter a conversation otherwise. This interaction can develop into suggestions for improvements that are meaningful to them, such as a ‘kids’-only garden’ with eatable plants in the place of a derelict yard located in an area lacking play spaces for children, which was suggested by some of the participants to the workshop experiment (Figure 4). While some of these proposals may be dealt with by groups of inhabitants (e.g., the derelict yard could be rented by local residents), others can be brought to the attention of the city council. These may refer to spaces, buildings or other urban features that are outside of formal planning frameworks; yet, mediated through the map, they can make planners aware of their importance for ordinary city users. As noted by the planners with whom the prototype was discussed, this could offer opportunities for new ideas, needs and opportunities regarding aspects of the neighbourhood that might not have emerged during formal planning processes.

Figure 4. Location-related suggestions for improvements (‘energy points’)



Furthermore, the visual features of the map-based website also represent a way to spatially indicate the outcome of the public engagement process and monitor progress. For example, an increased concentration of GPS traces could show an increased use of a formerly avoided area or improved pedestrian links. As pointed out by one of the interviewed planners, this has the potential to complement local development plans with visual representations of ‘soft’, abstract data, provided by everyday users of these spaces on an on-going basis rather than at specific moments of planning consultations. In addition, the map website also allows the recording and documenting of the process through which potential proposals have emerged, thus improving transparency.

THE CO-DESIGN PROCESS: AIMING TOWARDS A ‘COMMON LANGUAGE’

The co-designed platform prototype highlights the need – and offers the opportunity – for facilitating the ongoing and proactive participation of inhabitants in the development of the city, through sharing aspects that are meaningful to them in their daily lives (e.g., movement experiences). This is an important difference from current consultations, which are conducted at specific moments of the planning process (e.g., proposals for local development plans or comments to planning applications). The visual characteristics of the map allow this ongoing engagement process to be open and transparent, as each user can see her/his contribution to the collective map – hence each voice has the opportunity to be heard. This could foster a more positive relationship between city inhabitants and city decision-makers – one that is based on trust rather than on cynicism or negativity, which tends to be the prevailing situation in formal planning processes (McGuirk, 1995; Scott, et al., 2012). Moreover, as opposed to models encouraging the involvement of citizens as data generators (e.g., smart city initiatives), Urban Spacebook offers opportunities for the wider public to become part of the process of knowledge production about current urban spaces and their future development – a more empowering role, which challenges current power relations.

In addition to leading to the intended prototype participatory tool, the co-design process identified important aspects of participation, which would not have been possible otherwise. These additional aspects could be defined as the ‘metadata’, typically produced along the use of technology, but which tend to remain ‘invisible’ to the user or the non-expert eye. Thus, by alternating between spatial/physical and technological/virtual features, and encouraging first-hand interactions with urban space, the experiments identified the importance of ‘provoking’ an enhanced awareness of urban environments in order for those urban experiences embedded in everyday practice (and sometimes taken for granted) to come to the surface and be expressed. In doing so, the co-design process highlighted the need for complementing technology (e.g., GPS tracking) with reflective methods (e.g., written diary) and/or spaces for reflection (e.g., collective maps). This approach allows individual experiences to be expressed and shared among users and, potentially, between city inhabitants and decision-makers. While the views of residents may be sought as part of participatory planning sessions, the methods and tools used are rarely concerned with stimulating direct interaction with the environment or reflection, with few exceptions (e.g., Halprin & Burns, 1974). Yet, practices such as everyday movement, which are habitually repeated, contributing to ‘auto-pilot’ forms of interaction with the city and escaping conscious observation, could help identify important issues that need to be addressed. First-hand interactions with urban environments, as enhanced by location-aware technologies, could increase awareness of the city, including how these environments are designed, managed and used. In turn, an enhanced awareness can facilitate aspects usually taken

for granted, such as features of the city shaping (including limiting) everyday movement, to be noticed and expressed, in turn encouraging the user to be an active participant in the identification of potential solutions (rather than only perceived problems).

Incorporating opportunities for individual reflection has an important role in collaborative processes, so that a participant's own thoughts can be formulated (Sarkissian, et al., 2010) – an aspect which was also noted during the workshop group sessions carried out as part of the second experiment. In turn, this could also offer opportunities for creating a 'common language' – a common basis from which shared objectives (or vision) for spaces in the city can be developed collectively. Nevertheless, rather than losing individuality, collaborative processes such as those discussed here could maximise diversity (Hirsch, 2011) and offer opportunities for enhancing individual experience of the city. Tools now pervasive in contemporary society (e.g., locative technology and online mapping tools, which allow collaboration among users) could facilitate these opportunities and also the emergence of a 'space' where urban knowledge and experiences are creatively and collectively 'mobilised'. Rather than just passing through the city, new conversations with it could be started, while the act of passing through and its experience can be 'remembered' by using these technologies. Then, 'in our encounters with space, we might find more than our way' – 'alternative spatialities' (Dourish, 2006, p. 305-306), but also temporalities offering the opportunity 'to experience the urban landscape in new ways' (Sant, 2006, p. 6).

At a broader scale, nurturing capabilities for reflection among urban communities through meaningful interaction in 'public domains' can facilitate pluralism, thus moving "beyond the boundaries of standard democratic formality" (Jensen, 2009, p.150). In this context, locative technology can be explored as a way of bringing together such public domains – or the multiple mobile and electronic agoras that we engage with while moving through the city – and connecting them to the physical space of the city. This is important not only for empowering city inhabitants, but also for engaging civic leaders in creative and reflective ways of thinking about the city, which can open up new avenues of thought beyond established models of planning that do not acknowledge the increasingly blurred boundaries between physical and digital spaces. Furthermore, complementing existing formal planning processes and quantitative planning data with inhabitants' experiential data – or bringing together inhabitants' tactics and decision-makers' strategies through interactive processes that allow peer-to-peer learning – has the potential to open up new ideas about how more relevant urban policies and public services could be developed.

FUTURE RESEARCH DIRECTIONS

As basis for exploring concepts of co-production in relation to urban environments, the chapter has discussed an experimental co-design process, which led to a prototype collaborative platform for urban planning. The co-design process was aimed at involving potential users in the design of the digital platform and employed the notion of mobility (here, walking) as a medium for engagement. This approach builds on research into creating open and adaptable ICT solutions for collaborative urban planning (Saad-Sulonen & Botero, 2010; Saad-Sulonen & Horelli, 2010). Furthermore, besides offering a common starting point for expressing and sharing experiences of the city, mobility can be associated with developments in ICT and the increasing availability of personal GPS-enabled devices, which enable data logging on the move and the mapping of geo-tagged information.

In addition, the co-design process discussed here has highlighted how technology could be used as a tool for a collaborative production of knowledge for, and about, the city. In relation to this, sharing mobility experiences and drawing city maps through the means of GPS technology are put forward as part of an enhanced process of engagement between ordinary city inhabitants and city planners. Beyond the present role of data-generators, the co-design process indicates opportunities for technology to facilitate the (inter)active involvement of ordinary inhabitants in the important process of knowledge production about urban spaces and their future development. Inhabitants can become active participants in the development of the city, by sharing the city's quintessential (yet very little known) aspects – what city living is about and how it is experienced in daily life – using technologies at hand. A city map 'drawn' by people's movement and 'coloured' with their everyday life experiences can indeed offer a very different image of the city and of inhabitants' needs than those drawn up by city planners. In this context, collaborative digital tools could enable city inhabitants to have a more active role in establishing goals and taking collective action for improving their everyday environments.

At the same time, the co-design process has indicated the importance of nurturing capabilities for reflection among urban communities, which needs to complement the use of technology. This aspect of participation is particularly important when the aim is to access everyday life experiences of city spaces, sometimes considered 'non-representational' (Jensen, 2011). Complementing technology (e.g., GPS tracking) with reflective methods and/or spaces for reflection (e.g., collective maps) facilitated, in the case of this study, the expression and digital sharing of individual experiences among the participants. By extension, such reflective and interactive processes could be envisaged as facilitating communication also between city inhabitants and city planners. In addition, enabling the expression and sharing of experiences of the city embedded in everyday life could enable those involved in the process to be active participants in the identification of potential solutions – a precursor to action.

Opportunities for reflection, both for city inhabitants and civic leaders, together with meaningful interaction in public domains (both physical and digital) through the medium of technology, have the potential to facilitate the emergence of a 'common language' (Halprin & Burns, 1974). This can be illustrated with the collaborative platform, which resulted through the co-design process discussed here. On a broader level, rather than being consensus-focused (e.g., deliberative democracy, communicative planning) or conflict-oriented (e.g., radical democracy, activist bottom-up movements), the relationship between city inhabitants and civic leaders could be then conceptualized as dynamic, networked and spatial-experiential (i.e. experiences of spatial interactions with the city). This conceptualization is inspired by contemporary forms of social networking; the enhanced interaction between people and their environments offered by location-aware technologies; and the visual and dynamic GPS data representations with tradition in fields at the intersection between art and technology, such as the locative media art field (e.g., Polak, 2002; Wood, 2010).

In response to recent initiatives, which have put forward 'co-production' as a way of finding economic solutions to some of the current challenges faced by local governments and municipalities, the co-design process discussed in this chapter highlights additional dimensions of this concept. 'Collaborative production' is put forward as a useful concept for investigating the potential of mobile and collaborative technologies to enhance the processes of transforming urban environments into more resilient places. In relation to cities, this advances the discussion from inhabitants as consumers (e.g., of public services) to inhabitants as (co)producers (e.g., of resources, such as local knowledge). This conceptualization is inspired by open-source approaches, which place an emphasis on collaborative forms of knowledge production rather than consumption (Haque, 2007). While the term 'consumption' implies a negative

form of contribution (i.e. by detracting from existing and limited resources), the emphasis on ‘production’ places city inhabitants in a positive and more empowering role.

While the co-produced platform for engagement illustrates the potential of pervasive digital technologies for expanding participation and enabling collective action, future work needs to be conducted to develop the platform beyond its current conceptual stage. This relates to prototyping the platform in different locations and contexts; experimenting with different types of data, visualisations and applications; and exploring alternative business models to enable the running of the platform in ways that are compatible with its collaborative ethos. Moreover, a number of related challenges would also need to be addressed, among which: provoking and sustaining engagement in real-world situations; exploring contemporary issues such as a prevailing individualism, and cynicism and negativity regarding public participation in city planning and development; counteracting negative issues related to the use of digital technologies, such as ‘Big Brother’ forms of surveillance (Crang & Graham, 2007), the vulnerability of online databases (e.g., data privacy), the possibility that data may be used for malicious or powerful interests, or that the platform may be predominantly used by some groups of inhabitants to the detriment of others, deepening existing (or creating new) inequalities; and exploring the importance of contextual and local specificities, which may foster or discourage the type of engagement suggested by the platform.

CONCLUSION

Building on technological and societal implications of recent developments such as the open source movement, this chapter has explored ways through which the concept of ‘co-production’ (as related to citizen participation) could be extended beyond the current focus on the provision of more effective and cost-efficient public services. While the involvement of citizens in the provision of services is acknowledged to be a positive step towards enhancing their participatory role in the city, it is argued that co-production processes need to extend also to the ways in which a city is developed, managed and used. To facilitate such processes, new tools are required, which allow city inhabitants to be involved in identifying needs, establishing goals and taking collective action for improving everyday environments. Furthermore, alongside with these new tools, new forms of interaction and governance structures are also needed in order to stimulate and sustain collective civic actions.

The prototype platform discussed in this chapter offers a framework for an alternative form of urban governance, which is based upon a collaborative, ongoing and iterative process, distinct from the usual one-time participatory initiatives. It is argued that such extended forms of participation, enabled by pervasive technologies, could facilitate opportunities for inhabitants’ role in the city to shift from passive consumers to active producers. Acting in this role, inhabitants would be involved in the input (e.g., problem definition), the output (e.g., solution) and also the process in-between – an iterative process of co-producing the city with the decision-makers.

Technology-enabled experimentation has an important role in the process of co-designing digital tools that could enhance participation. However, it has also been shown that such approaches need to be complemented by opportunities and spaces for reflection in order to foster an enhanced awareness of everyday urban environments and the relationship with others with whom these environments may be shared. For example, the study has highlighted the value of GPS technology, including GPS-based maps and data visualisations, in awareness-raising processes that focus on experiential urban knowledge. Such maps can open up the engagement process by making people’s contributions visible, in a more

personal rather than a detached way (e.g., one-way information exchange via web-based channels, which do not allow for dialogue with, and among, users). The maps explored in the study discussed here offer opportunities for peer-to-peer learning and an enhanced awareness of the city – its challenges and potential – by sharing experiences and knowledge from a personal perspective.

Notwithstanding the limitations of the platform, many associated with facilitating positive and sustained broad-spectrum engagement through ICT, the co-design process through which it emerged illustrates the potential of co-production beyond economic solutions to public service inefficiency or utilitarian citizen-sensing initiatives. Rather than legitimizing austerity, co-production processes could widen (and deepen) the participation of city inhabitants in the development, management and use of their everyday environments by encouraging connectivity, communication, knowledge-sharing and peer-to-peer learning. Within such processes, collaborative technology platforms offer opportunities for new forms of urban governance, opening up the city and its infrastructures so that ordinary inhabitants are not mere ‘users’ or ‘consumers’ but active (and reflective) co-producers of knowledge and actions for a more resilient city together with the decision-makers.

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KEY TERMS AND DEFINITIONS

Co-Design: A participatory approach to design, which refers to the collective creativity of designers and people not trained in design who work together during the design process.

Dérive: An unplanned journey, usually through an urban environment, which is directed by the subtleties of the surrounding environment, as perceived through the subjectivity of the traveler, with the aim to encounter a new and authentic experience. The term has its origins in psychogeography and was adopted as a practice by the Situationist International movement.

Everyday Life: The various ways in which people act, think and feel on a daily basis, which are linked to the interpretation of self and to how one conceptualizes the relationship with others. It could be considered mundane, routine, natural or habitual – in social psychology, much of everyday life is considered to be automatic ('auto-pilot') being mediated by automatic cognitive processing of the features of the current environment, without any mediation by conscious choice.

Open Source: Generally, the term refers to a computer program / software in which the source code is made freely available to the general public to use and/or modify, with the aim to collaboratively improve upon the source code and share the changes within the community. The model is based on a decentralized form of production, as distinct from the centralized models of development usually employed by commercial software companies.

Planning: Here, the term refers to spatial planning, which is represented by the processes through which spatial plans are created by the public sector for the operation of a municipality, town or country. Spatial plans generally relate to the distribution of people and activities in spaces of various scales.

Resilience: The capacity of a system to handle disturbance (e.g., in the case of a city, changes and shocks to its social, economic, cultural, and technical systems and infrastructures) while still providing essentially the same function, structure, identity and feedbacks.

Smart City: Generally, the term refers to a city which uses ICT to enhance quality and performance of public services and infrastructures, to reduce costs and resource consumption, and to engage more effectively and actively with its citizens.

ENDNOTES

- ¹ The co-design process was part of a wider study into mobility practices and participatory approaches to urban planning.
- ² EveryTrail is a free iPhone and Android app, which allows tracing one's route on a map, geo-tagging photographs and uploading the GPS files on the user's webpage. Users can comment and vote on others' trips and photos, create groups and share their trips via Facebook and Twitter (<http://www.everytrail.com/>).
- ³ Crowdmap is a ready-to-use online mapping platform, which allows users to set up their own projects without having to install the platform on a web server (<https://crowdmap.com/>).
- ⁴ The digital prototype was developed with the help of Tim Redfern (independent artist) using open source code (e.g., OpenStreetMap and Leaflet). The website was populated with the data collected by the participants using EveryTrail.
- ⁵ The platform prototype was discussed with planners from Dublin City Council – the local planning authority of the study area – to find out which of its features and used they considered to be most useful in their work.

Chapter 8

Effect of Urban Computing on the Public's Perception of Place, Community, and Infrastructure

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ABSTRACT

The work presented in this chapter delineates the longitudinal experience of deploying an urban computing system that enables citizens to share and interact with digital content about the urban environment and experiences of people with it. It is part of an emerging and novel aspect of urban computing that expands research beyond simple optimisations of city functions towards a social and cultural approach that seeks to orchestrate complex socio-technical ensembles. Offering Collective City Memory as a service to citizens and enabling them to interact with it via diverse novel interfaces has uncovered the implications for city life that the introduction of urban computing brings such as the redefinition of spatial and temporal proximity and the effects on the perception of city space, fostering of social interactions, contribution to shared resources and participation in collective efforts.

INTRODUCTION

This chapter presents the extensive experience collected while iteratively applying an urban computing system that offers the Collective Memory of a City as a service to its citizens. In social and humanity studies Collective City Memory refers to memories about events that have occurred in a city and are shared within a community, they are thus characterised both by locality and by social contextualisation. It is related to Place as it is mentally anchored to the physical landscape, it is shared in the Community that sustains memories of past events and, as it is a quality that has always been shared in cities, it allows the researcher to evaluate the effect of modern Infrastructure on how people perceive and contribute to it. This research has selected Collective City Memory as a research probe that offers a novel perspective

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upon these core topics of urban computing; namely Place, Community and Infrastructure. The main research questions that thus guided this work sought to understand what is a public space and how urban computing alters the perception that people have of it, what is the people's role in the social sphere in this new era, and how does public infrastructure affect the adoption of novel urban computing services.

A strong motivation to conduct a study in this field has been the fact that urban computing is prominently positioned on the verge between the forefront of UbiComp research, which applies novel technology to people's lives, and the real world allowing the researcher to rapidly explore ideas with real users in authentic settings. The fact that urban computing selects as the setting of research the public space of modern cities where a profoundly wide range of people and cultures meet has also been a strong motive. The effect of its introduction in modern cities, although it has just started to become visible, is expected to be radical, comparable only to earlier ground-breaking technology-led transformations such as the electrification and the introduction of individual's automotive mobility. It has thus been a challenge and a fruitful research opportunity to undertake this work and study how the introduction of technology in modern cities transforms the experience that people live in this sociotechnical ensemble by redefining concepts such as spatial and temporal proximity, perception of city space, contribution and participation.

The cornerstone of the field of urban computing is the introduction of novel information and communications technologies in modern cities. Yet the city space is not neutral, unlike sanitised laboratory environments where research often takes place, city space is always and already populated and in effect culturally organised. The introduction of novel technology to it is an intervention that discloses its qualities and furthers our understanding of it. In this context urban computing research introduces interventions into the city fabric in order to study how people's perception is altered, what social practices may emerge, and even what is the right level or form of an intervention. This work has followed a longitudinal in-situ experimental methodology that exposed a close interconnection between design and research. It has performed the deployment of an experimental probe, the CLIO system, in varied authentic settings with real people. CLIO is a context-aware system able to support a number of applications in the urban environment and to offer access via various devices and interfaces with different capabilities; it invites people to contribute pieces of memory, to identify associations among them, to browse its collection, interact with it by rating or commenting, to explore the city through it and to engage in learning activities. On each deployment iteration an improved design of the probe was introduced that sought to disclose certain qualities of the space and thus allowed the authors to further explore and test a set of research questions.

The interesting results that have come out of this work span all three areas that urban computing focuses on. Through observations and log analysis the effect that a Place, in the sense of both location and character, on the content that users chose to view has been identified. The effect that urban computing applications can have on people's experience with and within the city, as well as the social interactions within the Community that can be spurred, have been demonstrated. Finally, the role of Infrastructure and its effect as different facets to information is discussed, focusing on the roles of mobile and situated gateways as well as whether public and owned devices are disjoint or supplemental.

This chapter is organised as follows; the Background section traces the emergence of the research of urban computing back to the origins of ubiquitous computing and discusses how this new field is differentiated; it also advocates for our selection of Collective City Memory as an appropriate use case to conduct research in this field. The next section presents the system design of CLIO, the research tool used in this work, shortly presents the settings in which it was applied and the evaluation data that were

collected. Results section presents in detail the outcomes of this work on the three selected research areas. The chapter concludes summarising main findings of this work and offering some future research outlook.

Background

This work falls in the area of urban computing, a research field that has unfolded from Weiser's (1991) seminal publications and ideas. His ground-breaking vision spurred a wave of research in the following decades and came to be realised in ways and forms not originally prescribed (Dourish & Bell, 2011) by numerous researchers attempting all sorts of interaction among users and everyday objects or surfaces of daily life (Greenfield, 2006). Human life, though, is enacted in settings of high complexity and within established social protocols, thus there has been strong criticism as to whether this vision has been utopian or dystopian and whether technology could ever seamlessly and effectively address social and cultural needs (Galloway, 2008; Dourish & Bell, 2011). In response to this criticism, a significant proportion of research has moved away from the original vision of proactive computing towards enabling people to be proactive and to orchestrate their environments (Rogers, 2006). Lately, there have even been voices calling the research community to offer instead of programming environments for professionals, tools for everyday people to program their environments (Abowd, 2012).

Halfway through the second decade of ubiquitous computing research, in a time when technology had matured enough to become adopted by mainstream users, the vision of the ubiquitous computing became diffused in modern cities and started to have an effect on both the physical form of the cities but also on the metropolitan experience of people (Greenfield & Shepard, 2007). As miniaturised, networked computing artefacts escaped the indoors limits, researchers started to observe the effect of their introduction in in-between places (Paulos & Jenkins, 2005), such as the streets of modern cities, or in third places (Shklovski & Chang, 2006), like parks and similar open public spaces. What they witnessed was that the perception of the city had been irreparably shifted, especially by the arrival of smart mobile devices (Bratton, 2009) that brought forward a massive bleeding of information out of the Internet and personal computers into the real world (Resmini & Rosati, 2011). Yet, what has made the emerging field of urban computing so appealing far surpassed the obvious introduction of mobility as a research theme; it was in fact the unprecedented heterogeneity which such places introduce in the research agenda (Williams & Dourish, 2006).

Over time several prominent researchers attempted to define the area of urban computing and prescribe core research themes in it. In this work, the authors adopt the positioning of the field in the intersection of computing, social sciences and urban planning. Furthermore, in the authors' view urban computing is a subfield of ubiquitous computing and as such it adds layers of information that become interwoven with the physical reality and produce new forms of practice rather than not distinct spheres of interaction (Dourish & Bell, 2011). At the same time, urban computing defies its ancestor's emphasis of information being available everywhere by positioning it somewhere (Galloway, 2008), thus setting a digital ground as a sort of foundation relating back to the physical world (McCullough, 2005) and reshaping our experience of spatiality, temporality and embodiment of space. This embodiment of space enables us to understand it, not in an Euclidean approach but rather in an anthropological one that takes into account its relation to established social practices and cultural organisations (Resmini & Rosati, 2011; Dourish & Bell, 2011). The authors further see urban computing as a field challenging architecture and urban planning in the sense that past requirements of architecture are now expected of software. Proximity, once the primary function offered by cities, is now most commonly experienced via smartphones and

shared co-presence applications, and the mechanical act of mobility has now subsided to the importance of its informational counterpart (Bratton, 2009).

In the authors' view the main themes in this research agenda are place, community and infrastructure, with equal emphasis on all three in respect to their effect on urban life. Previous researchers have already highlighted the dialectic between space and place; this work adopts place as a research theme for it reflects culture, memory and history (McCullough, 2005). People that inhabit places take them on, immerse themselves in them (Coyne, 2010), write the experiences on them, as if the places are mnemonic palimpsests, and thus reshape them (Resmini & Rosati, 2011). Place and community expose a common sense of insideness (McCullough, 2005); in the presence of urban computing, though, community building is affected. Co-presence might be an aggregation around shared interests; or it might even be shared not with the person physically sitting next to one but with another person on a shared co-presence application (McCullough, 2005). This redefinition opens up vast potential but also introduces constraints (Dourish & Bell, 2011) as it excludes particular people and ways of living from participating in a community (Galloway, 2008). The authors also adopt a broad view in infrastructure (Dourish & Bell, 2011), an element of the urban landscape that has the power to shape the experience of a space. In their view it spans from backend hardware, software and networks, that support communications, content storage and applications, to the devices that people adopt and utilise in the public space. The role of the devices that people interface with in the urban environment is particularly important as they extend the sensory range of their users and through habitual use shape new social practices (Coyne, 2010). Additionally, the introduction of infrastructure in a space constitutes an intervention that discloses its public and private qualities; as such it furthers people's understanding of it and provokes further interactions.

Applied in the intersection of computing, social sciences and urban planning, this work has had analogies to earlier applications in the field, but it also brings distinct contributions. A division in the field is often highlighted (Greenfield & Shepard 2007). Part of the research approaches people as mobile sensors that traverse the city collecting data that are then crunched to reveal patterns, flows and dynamics; examples include Paulo's et.al (2009) Citizen Science project and Calabrese & Ratti's (2006) WikiCity project. Others take a more social approach exploring the communal qualities of a city (Dourish & Bell, 2011; Galloway, 2008), e.g. Klæbe & Foth's (2006) Sharing Stories project or Hansen & Gronbaek's (2008) Urban Web. The approach of this work falls in the second broad area of research in urban computing. It has not sought to deploy expensive sensory infrastructure or to disseminate custom sensory modules to people and track collected data. Though there is much merit in such research endeavours, there is the argument that they overwhelmingly praise the potential of novel technology to address urban problems and neglect that it is rarely inclusive for the whole of society (Galloway, 2008).

The work presented in this chapter has been an in situ, longitudinal study on the introduction of an urban computing application that exploits available and affordable computing and networking infrastructure and evaluates the effect of such technology on the people's experience about the place they inhabit and the community they participate in. While this work fits well in the research field that studies how urban computing alters how people perceive and interact with the urban environment, at the same time it is differentiated from earlier ones in a number of ways.

The Sharing Stories project (Klæbe & Foth, 2006) similarly to this work explores the use of narrative and new media in community engagement. It addresses the emergent digital environment as a new social space that needs appropriate methods of interpretation. Its approach though it overly orchestrated; community building is approached via a number of workshops and content is created via a professional production line, not via an open, participatory approach as the one demonstrated later in this chapter.

The Urban Web project (Hansen & Gronbaek, 2008) attempts to bring the model of read/write urbanism, an analogy to Web 2.0 read/write approach, in action. It exploits technologies available at the time and produces some successful proofs of concept. Yet it does not offer a deeper outlook in the implications of their approach on urban life. Additionally, the settings in which they apply their demos exhibit a narrow social application as critiqued by Williams & Dourish (2006).

The Urban Probes project (Paulos et.al, 2009) has proposed a model of intervention in urban life that exhibits particular interest. It proposes deep observation of an urban setting and then the introduction of a lightweight probe that allows the researches to measure how urban computing influences, disrupts or expands city life. This approach has an analogy to the work presented here; the approach of the authors though is more broad as the interest has not been solely on how people experience place but also community participation. This work has thus introduced a heavyweight probe applied in a longitudinal research in varied settings and has engaged more and deeper feedback techniques, including, except for observations, also interviews, questionnaires and field trials.

The work presented here has paired well with the research of the Oulu University. Their contribution in the field is their urge towards the research community to work for visible, lasting results via orchestrated community-wide efforts. In order to facilitate this, they have developed an invaluable open city lab, which they offer to the research community as a real-world test bed (Ojala & Kostakos, 2011). Part of the work presented has been carried out in Oulu when it was invited and successfully applied in this setting producing fruitful results presented in following sections.

Prior to detailing the research methodology and results of this work, the morale of the use case selection is presented and how it relates to earlier research is presented.

Collective City Memory: An Appropriate Case Study

Memory is the mental capacity through which events are stored, preserved and recalled in mind (Sutton, 2012). Halbwachs (1992) set the foundations of research on the relationship between memory and society. "It is in society that people normally acquire their memories" and "it is also in society that they recall, recognize, and localise their memories". It is regarded that each individual memory can only be recalled in the social framework within which it is constructed. Thus the term "collective memory" was introduced in order to express the social contextualisation of all individual memories. Furthermore, Halbwachs sets the roots of identifying the role that space plays in shaping the collective memory (Olick, 2007), as every collective memory unfolds within a spatial framework. As cities are places where events that have occurred in the course of time are projected on, Boyer (1994) considers that a city as a whole can be regarded as a collective memory. Crinson (2005) later introduces the term "urban memory" referring to collective memory into the context of the urban environment.

A number of research or artistic projects generate content from the audience itself, creating diverse archives of collective memory, following either orchestrated or open participatory processes.

The Dutch government in 1999 introduced the policy of the "cultural biography", in which citizens would have a say in which artefacts should be made part of the collective memory of The Netherlands. The city of Maastricht extended the initial scope from material artefacts to the city as a whole; experts and citizens were invited to describe and to assess the qualities and identities of the historical city. This dynamic "cultural biography" was written in the form of a website and in the form of events on location. Similarly, in northern Australia the "Indigenous Knowledge and Resource Management" project

seek to make collective memory of Aboriginals community's knowledge traditions and provide it via a visually-based cataloguing-type software (Verran, et al., 2007).

The City of Memory project is an online community map of personal stories and memories organized on a physical geographical map of New York City. It offers an online interactive map that plots stories on the urban landscape either as points or as paths; content is open to anyone who wants to contribute. (ref) Analogous is the StoryMapping project, a project that aims to capture stories digitally about various places and to project them onto Google Maps. De Kreek and Oosterbroek (2013) explore local memory websites that emerge in modern cities and act as online spheres where residents collect their memories about places or experiences in their neighborhoods. They then propose a platform through which local knowledge, experiences and people become connected via the interconnection of these local memory websites by introducing city-wide compelling themes.

The Urban Pilot (Goel, 2002) and the Urban Tapestries projects (Angus et al., 2008) exploit mobile and ubiquitous computing technology and explore the potential of public authoring, which is mapping and sharing local knowledge, memories, stories, sensed information and experiences. They rely on the people who participate in sharing content to create it rather than on the consumption of mass produced content, therefore users are both authors and consumers of media as they go about their everyday activities.

Summing up the walk through the various systems that collect and share memories online we see that this has been an active field of research that has followed the evolution of the technology from Web 1.0 to Web 2.0 and then to the exploitation of mobile devices and ubiquitous computing. The dominant approach is to present the urban memory on the Web using interfaces that vary from the traditional browsing of digital collections to locating digital memories on maps. Current approaches, though, and even recent mobile based ones, have three major limitations; the first is that they permit limited interaction between the user and the memories as a user may simply view a few memories or add his own, the second is that memories are retrieved and presented via a simple search, based on location or description of content, and the third is that they do not promote the connection between the memories and the physical space as the user is usually not present at the site that is related to a particular memory.

This short survey of applications that collect memories and publish them as archive services exploiting available at each time interfaces demonstrates that users generally appreciate the value of collecting people's memories and experiences of a city and that such services can have a number of positive effects. Memories act as anchors in time, connect diverse generations, retrieve lost ambience in urban sites caused by the constant change, promote the sense of belonging as well as the formation of identity and transform sites that people routinely traverse to settings of exploration and learning. Collective memory, though, is not preserved by the space itself; it is the people's will to remember and to overcome the fact that the individual memories have a short time horizon that cultivates and sustains a collective city memory. In this process the interaction among people and memories is critical.

The authors of this work have opted to work on collective city memory as they consider that this is a fit use case to study the how urban computing affects people's perception and interaction with the city environment. The term collective city memory conveys the fact that these are memories that have occurred in the city and additionally highlights their social contextualisation. It is particularly fit for research on urban computing as this field studies the implications of embedding ubiquitous computing technologies into the modern cities (Paulos et al, 2004) and the interaction between humans and such environments (Paulos et al, 2009). Seen in this context, collective city memory is shared in the Community of a city, it is related to the Place as it is mentally anchored to the physical landscape and it allows us to evaluate what is the effect of modern Infrastructure on how people perceive and interact with the urban space.

ENRICH URBAN SPACE WITH CONTENT EXPLOITING NOVEL URBAN COMPUTING APPLICATIONS

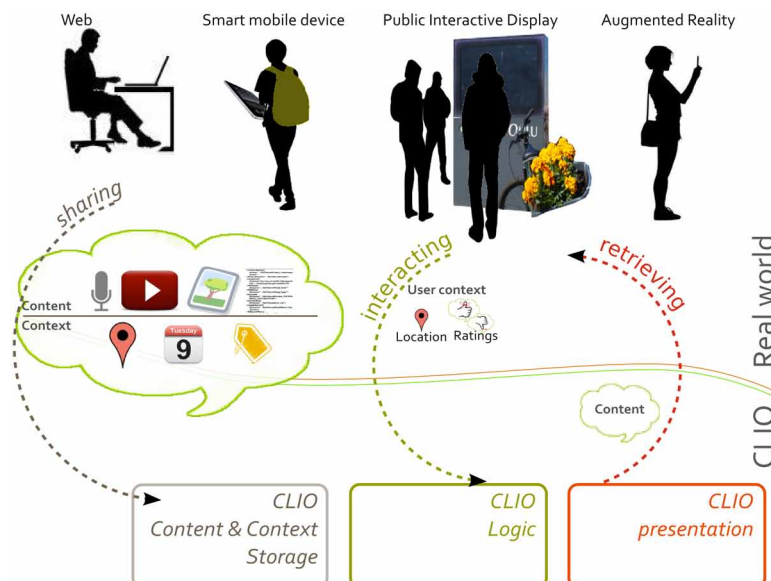
System Design

In order to perform field research, the authors of this work have designed and applied in varied settings an urban computing system called CLIO, an acronym of ColLective cItY memOry. CLIO has been designed in order to support various context-aware computing applications in the urban environment and to be accessed on various devices that host interfaces with different capabilities, Figure 1.

CLIO explores the possibilities that devices and infrastructure deployed in modern cities offer, ranging from personal smart phones to pervasive displays, in order to allow people to contribute pieces of memory, to identify associations among memories and to build the collective city memory. It preserves the collective city memory, it invites people to browse and interact with it and explore the city through it.

Its design has followed a modular approach that enables adaptation of design in different settings and evaluation of diverse technologies. The storage layer handles persistence of content and its related context that users share; content consists of media that describe people's memories while related contexts refer to when, where and what each memory is about. This layer also stores context, such as user ratings and statistics that is accumulated as users are interacting with the collective memory via one of the available interfaces. The logic layer exploits user context that client devices capture and provide to the CLIO backend while users are interacting with a CLIO interface as well as stored memories context in order to present relevant content to the users and to select appropriate recommendations. The presentation layer provides delivery of content in an appropriate format for each client interface; aiming to allow retrieval of content on diverse devices and interfaces this layer exploits both standard web protocols and custom APIs. In the real world, CLIO has been designed to adapt to an open set of possible clients, spanning from traditional web browsers, to mobile device apps and to public interactive displays.

Figure 1. CLIO system design



Appropriateness of Design

The design presented here has been appropriate in order to conduct research in the field of urban computing and address the research questions that guided this work for a number of reasons.

Collective City Memory is a part of the cultural heritage of a city that is shared in communities and is closely related to place. Thus it is a fit selection for a research that seeks to evaluate the impact of diffusing ubiquitous computing into modern cities beyond a technological standpoint, looking into the implications of embedding such technology on the interaction between humans and the urban environment.

Furthermore, deploying a computing system that mediates memory sharing that usually occurs in communities allows the researcher to witness how urban computing can catalyse social interactions, intergenerational dialogue and even explore its usability in learning processes.

Today a wealth of novel interfaces that blend digital content with the physical landscape is available. Such interfaces range from personal devices that people carry during their city traversal to public infrastructure that is deployed into cities. Evaluating how people perceive these new opportunities and whether public infrastructure affects the adoption of urban computing is a challenge for the urban computing research field. This design allows for the exploitation of diverse client devices in different settings, exploring the attitudes of the public towards the use of both public infrastructure and private devices.

Finally, the openness of this design and its ability to be adapted to different settings and exploit available infrastructure allows the researcher to conduct a longitudinal field-setting research. This is in accordance with a raising trend in the urban computing field to deploy and evaluate urban computing services in physical environments for a long run, aiming to avoid the bias in the observed results that are collected in unnatural lab environments. Detailed experience and evaluation results are presented in detail in the upcoming sections of this work.

Applications

Aiming to deploy our system on a number of settings the authors of this work incorporated an architecture that can be adapted to particular limitations and affordances; this architecture exploited open source components and open standards in order to achieve extensibility, reusability, transparency in component replacement and openness to experimentation. On the real world, a number of client gateways were employed gradually moving from an indoor setting to mobile access and reaching interactions on the urban environment exploiting public permanently situated interactive displays. On each iteration, a new client interface was designed and tried out; each interface offered varied levels of supported user interaction, coped with the limitations that the respective client gateway posed, but offered a unique angle on how people perceive public space, how urban computing affects this perception and what roles people take up in this space.

The first version of CLIO was applied in Corfu, Greece, inviting people to share personal memories and contribute to the collective city memory of their city. The main purpose of this early implementation was to demonstrate the idea and receive early user feedback. The first public client interface was web based, a simple and familiar interface suitable for the general public. Through this the public could share a memory as a combination of text, photo, video or audio, Figure 2; client interfaces allowed the public to explore collected content via a map or a tag cloud view, Figure 3.

Figure 2. Web based version of the CLIO sharing application, in Corfu

Collective city memOry

Μοιραστείτε μια φωτογραφία

Τι είναι αυτό που θα θέλατε να καταθέσετε;

Τίτλος:

Ανεβάστε τις φωτογραφίες σας:

Έως 10 αρχεία και μέγιστος συνολικός όγκος 10MB. Για περισσότερα από ένα αρχεία, επιλέξτε τα πρώτα στην καταμέτρηση το πλήθος CLIO.

Ονόματε αρχείου (προαιρετικό):

Μπορείτε να δώσετε μια περιγραφή της φωτογραφίας:

ή θα θέλατε να συνοδεύσετε τη φωτογραφία με μια περιγραφή:

Όνομα αρχείου:

Σε ποια πόλη, ποια περίοδο ή ποια γεγονός αναφέρεται η ανάρτησή σας;

Χρονολογία (ημερίδα):

Τόπος: επιλέξτε ένα από τα 19 σημεία ενδιαφέροντος ή προσθέστε ένα νέο.

Επισημάνετε κείμενο:

Αφήστε κλειδιά (tags) που θα βοηθήσουν στην αναζήτηση:

Αφήστε στοιχεία για εσάς:

Όνοματεπώνυμο:

Αίμα Μην για εσάς:

e-mail:

Ημερομηνία γέννησης:

Κατεβάζετε μόνο σας την ανάρτησή σας ή με τη βοήθεια κάποιου άλλου:

Κατεβάζω εμένα την ανάρτησή μου.

Κατεβάζω την ανάρτησή μου με τη βοήθεια αυτού:

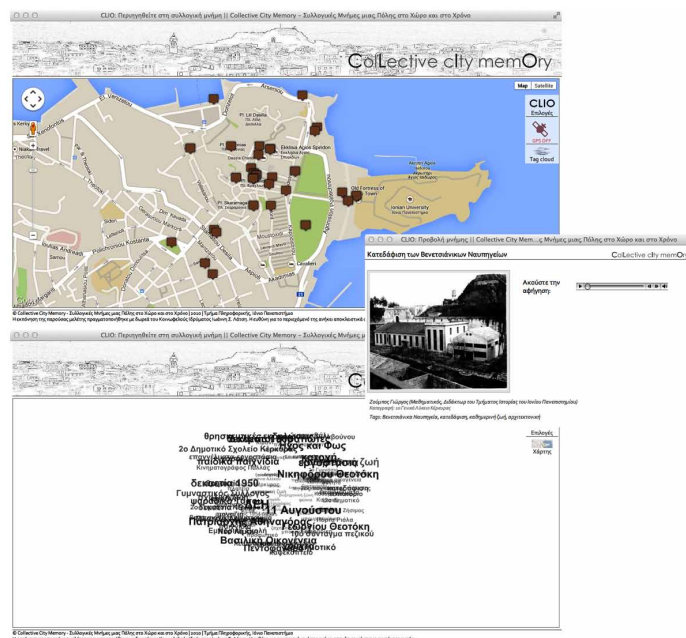
Παραχωρώ αυτή την ανάρτησή μου:

☐ Έχω διαβάσει τους πιο κάτω όρους και παραχωρώ αυτή τη στιγμή στη μέλη της "Συλλογικής Μνήμης μιας Πόλης στο Χάρο και στο Χρόνο".

Καταχωρήστε την ανάρτησή μου

© Collective City Memory - Συλλογική Μνήμη μιας Πόλης στο Χάρο και στο Χρόνο (www.clio.gr) [Τμήμα Πληροφορικής, Πανεπιστήμιο Ηρακλής] Η ανάρτησή της παρούσας μελέτης πραγματοποιήθηκε με δωρεά του Κοινοβουλίου Ηρακλής, έκδοσης 2. Αθήνα. Η μελέτη για το περιεχόμενο της ανάρτησης αποσκοπεί στους σκοπούς αυτής.

Figure 3. Web based clients to CLIO content, in Corfu



In an attempt to explore whether it is feasible to infuse the collective city memory into the city landscape and attach it to city landmarks in Corfu the authors of this work experimented with printed two-dimensional barcodes, Figure 4(a). This early exploitation of mobile devices leveraged the ubiquity of their presence and the extension of networking into the city, while building on web based content delivery. In order to fully exploit the potential offered by the abundance of mobile devices in the city landscape, an application (app) for personal mobile devices was later developed, Figure 4(b).

The next major CLIO implementation iteration was performed in Oulu, Finland. CLIO was invited as a finalist of the 1st International Open Ubiquitous City Challenge (Ojala & Kostakos, 2011) to be deployed on the city's public interactive displays. CLIO interface was redesigned and adapted to integrate the citywide open access WiFi network and the array of large, public, interactive displays installed in several indoors and outdoors locations, Figure 5.

The last explored interface was based on the augmented reality capabilities that modern mobile devices offer leveraging the ever-expanding array of integrated sensors. An off-the-self application offering a rich application programming interface was adopted and exploited to make CLIO available to interact as a hidden information layer within a city, Figure 6.

Evaluation Data

Through the course of these deployments a wealth of user evaluation data was collected. Evaluation moved gradually from the collection of qualitative feedback on the concept of producing a system that mediates collective city memory to acquiring a large volume of quantitative data collected by background monitoring of user interaction with our system in the wild. The initial set of users involved in Corfu

Figure 4. Exploiting mobile devices, (a) as gateways to content encoded in embedded two-dimensional codes, (b) via a custom app

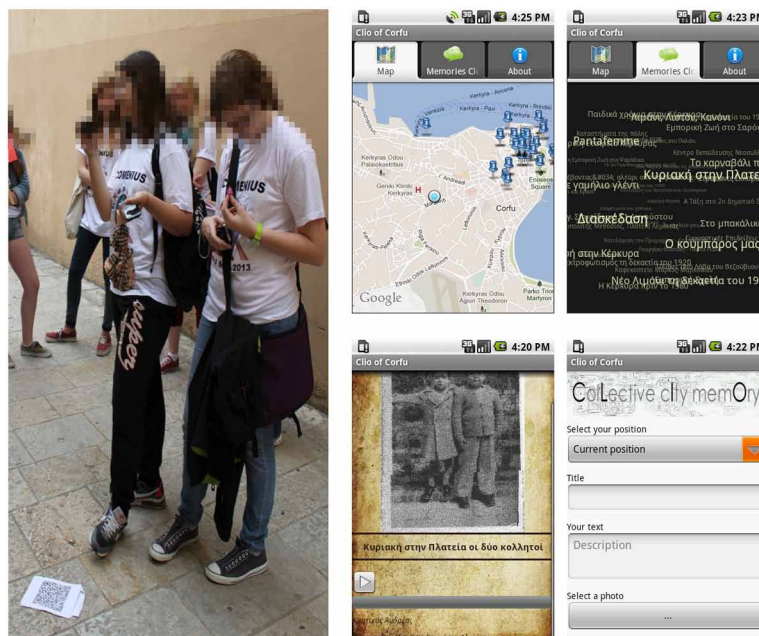
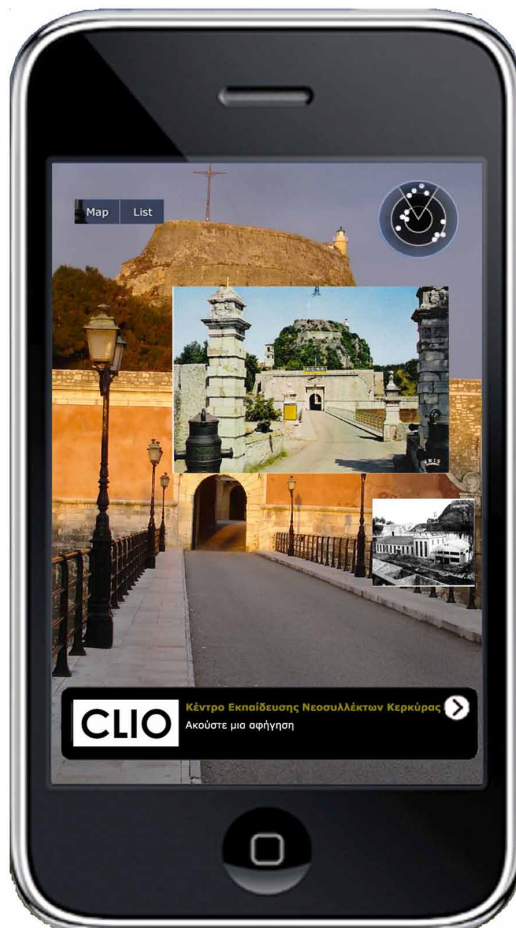


Figure 5. CLIO on public interactive displays, in Oulu



Figure 6. Leveraging an augmented reality interface with CLIO



were a group of high school students and teachers who evaluated the first web based version of CLIO and performed a number of outdoor activities exploiting two-dimensional barcodes that were embedded in the city landscape. Later a dozen of users apt with smartphones use provided feedback on custom app interface to the CLIO system. The last iteration of evaluation was performed on a large scale in the city of Oulu when CLIO was deployed on the municipal array of public interactive displays for a period of six months. More that twenty-four hundred launches of the public displays application were recorded and after thorough clean-up of the logs, which consisted of more than forty thousand entries, half of them were deemed substantially interesting, exposing engagement for an adequate timespan and meaning interaction sequences, to be further analysed. Alongside this mass observation task, a set of user trials, interviews and questionnaires were carried out in Oulu, engaging two dozens of randomly selected users of varied ages and technological aptitudes, evaluating the public displays application and the augmented reality interface.

RESULTS

Analysis of the wealth of qualitative and quantitative data that were collected during the deployment iterations of CLIO allowed the authors of this work to reach a number of conclusions on the three areas that this work has focused on, namely the Place, Community and Infrastructure.

Place

The first axis around which urban computing research unfolds is the effect that the introduction of novel computing technology in the city landscape brings to the public space and the perception that people have of it.

Depending on the Setting and the Interface that They Engage with, Users Perceive a Different Sense of Blending between Content and Space

Offering visible anchor links of content in the physical space, as this is achieved by the introduction of printed quick-response codes on landmarks, was characterised in user interviews as calm and subtle anchoring of digital content to the physical space and as a fit application of this technology, one that conveys a sense of attaching the collective memory to the city. Users also reported that the barcode encoding stimulated their curiosity in uncovering the content behind it, more than the usual signs that are embedded in a city marking such landmarks. Especially younger generations were intrigued to locate as many codes as they could, engaging themselves in a treasure haunting game. Users of all ages also considered this a good exploitation of the smart devices that more and more people carry on them.

Removing the visible anchors and exploiting the smart devices that people carry as pervasive gateways to a hidden layer of omnipresent content was attempted exploiting two different views; a familiar map-based one via a smart-phone app and a novel augmented reality based one. In both cases users responded that offering collective city memory as an omnipresent digital layer that one may interact with anytime, by simply engaging with a familiar smart mobile device, conveys a strong sense of infusion, yet comparing the two they were clearly impressed of the augmented reality view as the appearance of

content augmenting their physical surroundings relates the two far stronger than the familiar map based view and triggers a contrast between the present and the past.

Finally, pervasive displays located in places where crowds gather were exploited as physical anchors to digital content. People who used CLIO on a public display reported that this anchoring is particularly important as it adds well-known fixed points into the city landscape that people can turn to without the need to carry modern and often expensive personal devices. Thus, while exploitation of this sort of public infrastructure does not blend content with space in the sense that access via mobile devices do, people reported that they consider it important as it levels entry technology barriers for the wide audience and redefines the locations of the public displays as hotspots where the physical and the digital selves of a city meet.

The Place and Setting Where Users Interact with a System has an Identifiable Effect on What Content Users Choose to View

This particular finding has been supported both by the experience observing user trials, in various steps of our deployment, and by log analysis of users of CLIO on the UBI-hotspots.

Initial observations of this fact occurred in the early evaluation period in Corfu, when groups of school teachers were invited to evaluate the early web-based CLIO interface. When interaction with CLIO occurred in groups, typically of two or three persons in front of a shared computer display, people would engage in discussions about the memories that they viewed, seek similar ones or exchange their own memories in threads linked either to a certain location or a theme.

This observation was reinforced by the logs of user interactions that had occurred randomly in the wild by users on the public displays of Oulu. As a metric here authors chose to study the first selection of a user when launching the map view. Figure 7 (top) depicts CLIO content scattered around the city of Oulu while Figure 7 (bottom) depicts which content users of the five public displays around the Rotuaari pedestrian area first select. Relating the two illustrations one can note that proximity to content is a strong motivation when randomly picking content. Logs reveal that proximity has been more attractive than even user interface imposed bias, such as larger markers as more users selected as a first pick nearby content than those who were lured by larger markers which denoted multiple content items at the same location.

A similar effect has been observed after the analysis of system logs regarding the use of the Cloud view on the city's UBI-hotspots. Figure 8 visualises log analysis of the words that users of CLIO selected on their first click on the Cloud view. This spontaneous action was deemed again as the one catching the unbiased interest of the user, when presented with a collection of themes related to the content of CLIO. Figure 8 (top) depicts the ten most commonly selected tags, ordered in decreasing popularity; following Figures (middle and bottom) depict how this order is affected when UBI-hotspot locality is considered. In the Toripolliisi area (Figure 8 middle) the theme that has been, by far, most popular is music, followed by fun, summer and Oulu landmark, while in the Rotuaari area (Figure 8 bottom) we see that the most common tags appear to be fun and social. This variation can be attributed to the character of each place. In the case of Toripolliisi being located on the market square, a location used for music concerts and festivals throughout the summer and also located adjacent, and actually named after, the iconic Toripolliisi statue, the most well-known city landmark and meeting point for locals and visitors. Rotuaari is a lively social area, transportation hub, also hosting the Rotuaari Piknik, a multiday festival offering various on stage shows and a leisure setting for picnic in the heart of Oulu city.

Figure 7. Effect of place on user selected content

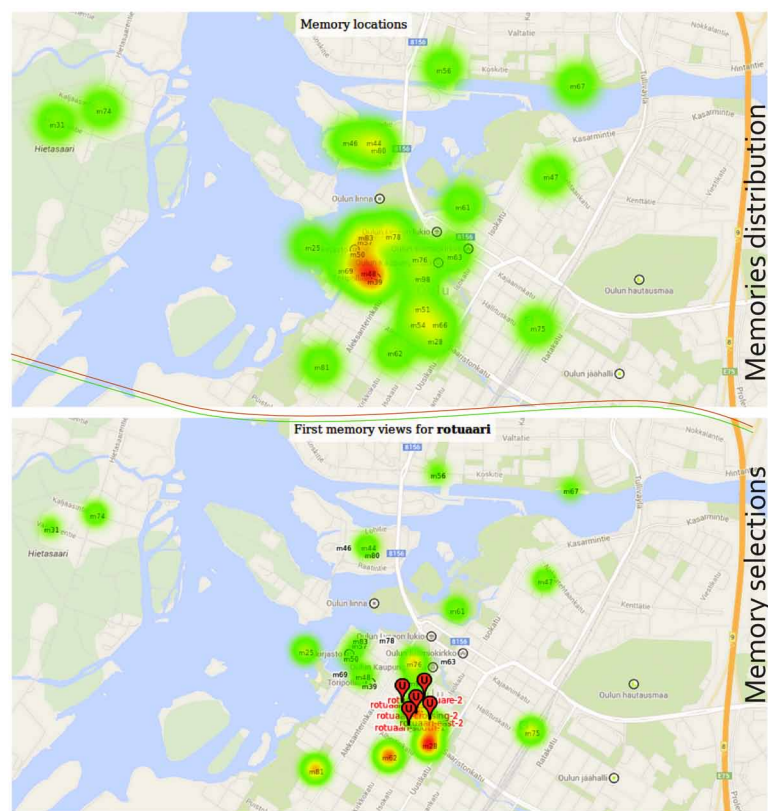
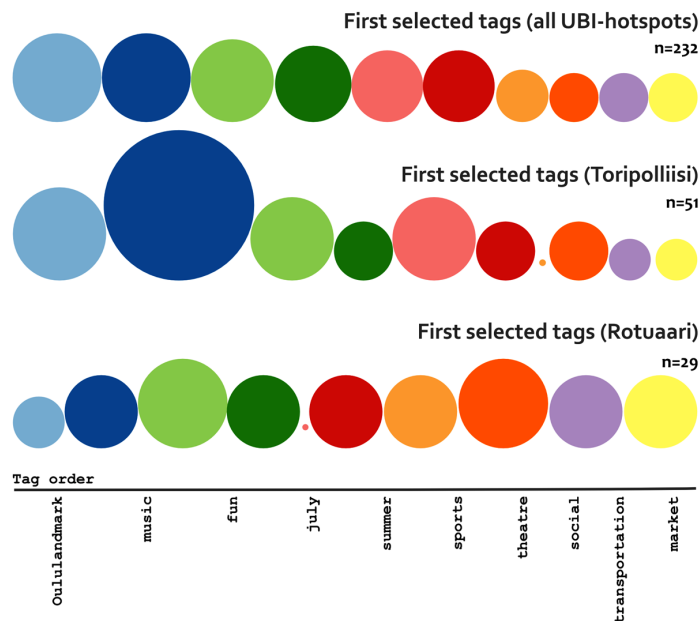


Figure 8. Effect of setting on user selected content



Summing up, usage analysis of both the Map and the Cloud interfaces on the public displays reveals that the location and the character of the place where the user interacts with the system have an identifiable effect on the content that he selects to view. This is not the only affecting factor, as the user choices are affected by various other parameters, among which the design of the UI, but the effect can be traced both on user observations and on the traces of interaction that the system collects.

Community

The second axis that urban computing research studies is how the advent of this technology alters people's role in the social sphere.

Urban Computing Applications can be Facilitators of Sharing Within a Community; but They are not Unbiased

While sharing content nowadays is a ubiquitous action, this usually occurs in social media; it has been a challenge in this work to achieve sharing on a system that publishes content openly in a city via a number of interfaces that the general public can reach.

Results from both Corfu and Oulu demonstrate that people are willing to, and actually do, share personal memories aiming to create a collective city memory. In the case of Corfu, students acting as interviewers collected personal narrations most of which were accompanied with old photos; common topics often emerged, as people of the same generation with similar life experiences were interviewed. In the case of Oulu most of the collected memories were a combination of photo and a short text as people shared memories in-situ exploiting personal devices and the city ubiquitous infrastructure, thus shared memories were usually spontaneous recollections of recent events.

Comparing the experience from those two different settings it appears that the collection methodology has a significant effect on the content that is shared. In Corfu content was usually memories in the form of structured short texts or narrations accompanied by old photos; in Oulu most of the content was recent experiences in the city expressed as short text accompanied by media available on the devices that people carried. Thus the setting of sharing imposes a strong bias in the resulting collection.

Urban Computing Applications Can Offer More Than Utility Functions; They Can Have a Personal Effect and Users Can Experience Strong Emotions

An observation that we repeatedly came across during our deployments was that viewing content provokes related recollections. This, of course, relates to fundamental research in the field of memory by Halbwachs (1992) who stated that "it is ... in society that [people] recall, recognize, and localize their memories", what is novel is that this process can be mediated by a computing system operating in a city environment. People using CLIO on all interfaces, such as personal computers or smart mobile devices and public displays, recall similar events and often seek to communicate their recollections.

During the observations, the authors of this work witnessed that people experienced strong emotions while viewing memories, like laughing or arguing, and recalled and sought to share similar memories. Additionally in interviews, users responded that they would be interested to share content in the future. The fact that, nonetheless, most users adhere the "consumer" role is attributed to the sharing process that one has to go through, which was often considered too technical.

Urban Computing Applications Can Spur Social Interactions

Observations further reveal that a system like CLIO triggers social interactions. Individual users on average spent more time and viewed more memories; whereas groups started talking, commenting and engaged in long conversations. According to the authors' experience, a catalyst that may enhance social interactions is the availability of shared infrastructure. In Corfu, where no public infrastructure was available social interaction occurred groups of users were invited to try out CLIO using shared computers. In Oulu, where public displays were available throughout the whole city, it was typical that groups of people started discussing.

Social interactions can furthermore be fostered as mediated experiences. People viewing content on CLIO, commonly rated it, thus engaging themselves with it and offering others a record of their agreement or disbelief. Accumulated ratings acted as a measure of a memory's consensus in the community. Approaching social interactions from another angle, users of CLIO on mobile devices on interviews required sharing features, either privately to friends or more openly on social media. Even users who stated that they would be reluctant to be identified with social media profiles on the public displays, they acknowledged that offering CLIO as an application on certain media, as Facebook, could assist people in sharing content and recommending it to others. Given the intrinsic sociable nature of such media, their integration with an urban computing application could certainly encourage social interactions as well as sharing.

Urban Computing Applications Can Promote Intergenerational Dialogue

A particularly important niche aspect on social interaction and an uncommon accomplishment for computing systems is communication among different generations. The work presented here has been able to promote it on all its deployments. During the first deployment young students collected memories from older family members or friends; youngsters who engaged in this activity reported that they enjoyed the sense of sharing that they experienced when interviewing their ancestors and that this had been an experience that has brought both generations closer; some of the interviewed students reported that "until now I felt that I had nothing in common to talk with my grandparents" and "me and my grandfather used to play in the same square, but the surrounding shops are not the same." On the deployment in Oulu, friends or family groups of different generations often grasped the chance to engage in a discussion about their roots and the future, leveraging in front of the displays the ease that youngsters demonstrated in interacting with the interface and the recollections that elders could share.

Urban Computing Applications Can Be Valuable as Learning Tools

Finally, this work has demonstrated that an urban computing system can be exploited in a number of learning activities. In early deployments students are invited to enrich CLIO by collecting and annotating content as well as to carry out a number of outdoors scenarios exploiting smart mobile devices. In all cases students expressed their excitement about being able to use smart devices in learning activities and especially for taking a class outside their classroom. They also reported that the system had an impact on how they see their city, as they learned new things about it and the experienced places that they considered as "in-between" spaces differently during their playful activities. Teachers also found it interesting to use novel technologies in order to teach traditional subjects like local history and considered

particularly encouraging the fact that their students were passionate on carrying out outdoors activities that strengthen their collaboration, communication and inquiry skills.

Infrastructure

The third axis around which urban computing research unfolds is the study of the effect of infrastructure on the adoption of such applications. Infrastructure spans in a number of levels ranging from network availability to client devices and interfaces that offer access to urban computing applications and services.

Network Connectivity as a Catalyst for Urban Interactions

By definition urban computing applications focus on the use of technology in public environments, such as cities, parks, etc. (Paulos et al, 2009). As such a major requirement is often network connectivity that may enable on the spot interaction with content or other users of a system. Experience reveals that network infrastructure significantly affected people's experience with our collective city memory system and in general their ability to interact with urban computing applications. It is acknowledged by citizens as a potential advantage of a city and local authorities are urged to consider offering networking as utility to citizens.

Mobile Devices as Novel Omnipresent Interfaces

Mobile phones that everybody has been carrying since the turn of the millennium have nowadays transformed themselves into the most abundant pervasive computing device in use in cities. Smartphones sales have surpassed those of "dump-phones" (Gartner, 2013) and users of smart-phones become the dominant group in the mobile communications eco-system. It is, thus, natural that smartphones have become the omnipresent interface to applications in the urban landscape offering a number of advantages over earlier technologies.

Interaction via a mobile interface was reported to as particularly satisfying as users could interact with the system freely in the city landscape, following their pace, exploring whereabouts and experiencing novel views. Exploiting a mobile device as a gateway to a service offers the strongest blending between content and space, as the former can always be revealed on top of the latter, by simply interacting with a personal and familiar device. Additionally, smart mobile devices carry or have access to personal content thus enabling instant on the spot sharing.

Public Displays as Well-Known Shared Gateways Levelling Technology Barrier

As popular as smart mobile devices might be, public displays will always be a community-shared infrastructure offering access to novel services for the broad public. Deploying such interactive interfaces, that anyone can approach and leverage, raises the technology barrier that a significant percentage of the general public will always face. Interviewed users responded that they appreciated the existence of the public displays as beacons in space that attracted them to access the service. Experience also reveals that such infrastructure tends to stimulate social interaction among people ephemerally sharing it; families or friends that were observed doing the system trials would always start discussing while viewing content

and, on occasions, people who happened to meet for the first time in front of a display would exchange few words about the displayed content or about the application that presented it.

Longitudinal experience has shown that public interactive displays can be utilised both as interaction catalysts in the city landscape in order to provoke social interactions and as well-known shared gateways to novel services for the general public of a city. Yet the location where a public display is situated has a huge impact on its effectiveness. Both indoors and outdoors locations can be equally suitable locations to position a public display, but it appears that effective will be those displays that are on locations where people would naturally idle, not those that expect to interrupt a user's action in order to be utilised. An application that seeks to attract a user's attention while he is on the move should exploit personal mobile devices that can deliver context-aware unsolicited notifications.

Public or Owned Infrastructure; Disjoint or Supplemental

Revisiting field experience the authors of this work have come across a dilemma that often emerges regarding infrastructure in public spaces; which is a better development track, public or owned, and are these disjoint or supplemental. The long experience of deployments in two cities advocates in favour of a combination of the two tracks where one supplements the other.

Experience delineated in this work has shown that in order to achieve seamless access to urban computing services for users who might freely roam in the urban space some sort of open, free and coordinated access is required. This could be implemented as a network offered and controlled by local authorities or as a network which public and private bodies contribute to, centrally coordinated, so that the users who exploit it can roam freely, transparently switching providers. If this is not achieved, the effect is either a fragmented network space, with unconnected areas, or the user has to resort to commercial carrier networks that he can afford. The former case breaks the user experience, while the latter limits the audience that can leverage urban computing applications.

Regarding the infrastructure that users exploit to interact with novel urban computing services personal mobile devices are steadily becoming the dominant means of access. Yet experience shows that public infrastructure, like interactive displays, can have a vital effect on a number of levels. Being well-known beacons in the city landscape, they attract the general public and thus are able to disseminate new services. Another reason advocating for the use of public interfaces is that they act as social catalysts impugning the isolation that is often observed among users of mobile devices in public areas (Hakuta & Toch, 2014). A shortcoming of the public displays though is the fact that, due to technical limitations of large tactile displays or privacy concerns of users who interact with them in plain view of others, users consider it often difficult or simply undesirable to use them as input devices. This limitation is considerable for applications like CLIO that require content sharing or other user input. An effective integration of public displays with personal devices can prove appropriate. Simple forms of such integration deserve to be researched as experience has shown that the majority of the public is often ignorant of the skills required for this interaction or troubled by technical shortcomings when attempting to perform it.

CONCLUSION AND FUTURE WORK

Looking back on the experience presented in this chapter, the authors have produced an urban computing system that offers a number of novel technological characteristics but at the same time involves the

whole society, an uncommon accomplishment for the research field of urban computing. Young students, older family members, tech-savvy and late technology adopters have all participated, exploiting diverse facets of the same underlying system. This work confirmed earlier works, which proclaim that people experience the introduction of computing in the city landscape not as a dichotomy but as a gradient, when users were asked to evaluate their perception of blending between content and space that is afforded by CLIO's interfaces. At the same time, though, by utilising in the same context diverse interfaces, a differentiation from earlier works, the authors of this chapter were able to document the strong user wish for visible seams between the physical and the digital worlds, as these remind people of the existence of an intangible layer and attract them to interact with it. Additionally, through the longitudinal field work and log analysis a number of parameters that affect people's interest in content and their seeking strategies in the urban space were inferred.

Furthermore, looking into how urban computing affects communal aspects of a city; this work demonstrates that urban computing applications can be sharing facilitators, but they are not unbiased ones. The sharing methodology involved directly affects the content that will be collected and the adoption of an application by wide and diverse audiences. The authors also delineate how appropriate design of system and user processes can lead to added value results, such as the promotion of intergenerational dialogue or the ability to exploit an application as a valuable educational resource, avoiding narrow social inclusion, so often criticised in works of this field. They also reveal how an application about the urban landscape can offer more than a utility function and have personal and social effects, such as provoking strong emotions, leading to personal recollections, affecting how people embody space and even spurring interactions with other people. Finally, they uncover people's attitudes towards public infrastructure, compare it to the use of personal devices and outline the catalytic effect that infrastructure deployed in modern cities can have on interactions. Via the parallel deployment of various interfaces, authors witnessed that the ability to interact with a service as CLIO in a public space might foster a sociable mood to a person, the affordability of shared public interfaces, however, lures people out of the personal territories that smart mobile devices often establish and engage them in vibrant social interactions.

FUTURE RESEARCH OUTLOOK

Recollecting on the experience with CLIO, authors of this chapter have witnessed that cities are not just infrastructure and services; while all modern cities share the same infrastructure and offer similar functions each and every one has evolved a unique character reflected in everyday life and culture. Cities are the people that inhabit them, their memories, stories, concerns and the culture that develops through social interaction. In a time when integrating computing infrastructure in modern cities is becoming a mainstream seeking to assist city stakeholders to better manage numerous sides of city life, the authors of this chapter propose that more research should be conducted on the relation between urban computing and the sociable smart city (Christopoulou & Ringas, 2013), a term they introduce in order to describe a city rich in infrastructure, which combines and exploits both people and artificial intelligence, empowering and engaging people in activities where urban social interactions thrive aiming to advance the quality of life and culture. In this context they propose a further look into how urban computing may empower people to engage in collectively shared issues and develop a sense of belonging and responsibility, as well as further research into how the tangible quality of space can be supplemented with digital tools and new media in order to connect people and their experiences with the city or design and implement learning

processes, playful activities and cultural events. In their view, the approach towards the city space is not a dichotomy among physical and digital spaces; instead they consider that urban computing's relation to information technology, social studies and urban planning can redefine city spaces converting them to ambient socio-technical gradients.

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KEY TERMS AND DEFINITIONS

Collective City Memory: Memories that have occurred in the city, bearing a social context that assists in their preservation and perpetuation.

Collective Memory: Term that describes the social contextualization of all individual memories.

Smart City: A city in which investments in human and social capital as well as traditional and modern communication infrastructure fuel sustainable economic development and a high quality of life, with a wise management of natural resources, through participatory action and engagement.

Sociable Smart City: A city rich in infrastructure, which combines and exploits both people and artificial intelligence, empowering and engaging people in activities where urban social interactions thrive aiming to advance the quality of life and culture.

Socio-Technical Ensembles: A setting where people and technical interventions coexist in an orchestrated manner.

Urban Computing: The integration of computing, sensing, and actuation technologies into everyday *urban settings and lifestyles*.

Urban Informatics: The study, design, and practice of urban experiences across different urban contexts that are created by new opportunities of real-time, ubiquitous technology and the augmentation that mediates the physical and digital layers of people networks and urban infrastructures.

Urban Memory: A kind of collective memory that is constituted by individuals' experiences within the place itself and through its history and social environment.

Chapter 9

Design and Development of Sentient Collective Urban Spaces

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ABSTRACT

This chapter aims to envision design approaches for creating ubiquitous interactive spaces which can empower the users to shape and reshape their living environments. It starts with the discussion of the affordances of networked sentient technologies to facilitate cycles of reflexivity through a comparative case study. Based on this analysis, the author distils key principles for future practices including: incomplete, dynamic architectural program, continuous representation of the user needs, incorporation of user variety and differences, embracing open-endedness, self-organization and spontaneity in use. Following these principles, the author reveals a conceptual design for a sentient space in Ghent as a means to demonstrate action possibilities latent in ubiquitous spaces. In conclusion, the author shares lessons learned and elaborates on future directions.

1. INTRODUCTION

Today, conceptualizing sustainable spaces that are capable of change is one of the biggest challenges in urban-architectural design practices (Burdett, 2013, p. 349). In order to address this challenge, it is necessary to develop alternative ways of designing which entail a dynamic understanding of urban-architectural spaces. These should facilitate recognizing the evolving modes of urban spatial production and diverse types of appropriation of these spaces by human and non-human actors.

The most significant difficulty in achieving these goals is the increasing complexity of the urban spaces and problems. Throughout the world, rapid urbanization and the growing mobility of the humans, goods and services have created a plethora of urban issues at an unprecedented level. These are radically different than the problems of mathematics and engineering sciences and range from gentrification to ecological sustainability, spatial identity to urban decay (Heynen et al., 2006). They are so complex,

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ill-defined and ephemeral that it is not possible for designers and planners to produce optimal solutions to these problems in a reasonable timeframe.

Moreover, the data necessary to handle these problems are often inaccurate, incomplete, dated or disconnected from everyday life since it is impossible to sense and measure all meaningful flows and activity in our cities in real-time. Adding on to this challenge, the stakeholders in design process disagree about their needs, requirements; their values are in conflict and their attitudes change in time. In this regard, novel urban design practices are required to continuously engage various stakeholders into the design process and explore available alternatives with their feedback in a bottom-up manner until certain criteria are met; in other words, produce satisficing solutions which suffice and satisfy a set of needs (Simon, 1996). Due to the challenges introduced above this task is beyond the capacities of traditional top-down urban design practices.

In order to address the ill-structured urban problems designers and planners need to find novel ways of facilitating adaptability and socio-cultural engagement through design which is capable of addressing the spatial dynamics of contemporary urban life (Burdett, 2013: p. 350). To reach this goal, it is necessary to construct novel ways of seeing architectural and urban spaces that incorporate change, self-organization and time as enabling spatial qualities. Such practices require the recognizing and sensing of qualities of incrementality inherent in urban space, leading to a dynamic understanding of urban spaces (Shepard, 2013, p. 223).

In this context, emergent information and communication technologies (ICTs) and relevant novel ICT-enabled design methods developed in the last decade provide diverse possibilities for empowering the designers. Among those “smart cities” is a powerful vision which refers to novel methods for creating urban spaces increasingly composed of and monitored by pervasive and ubiquitous computing. Although it became a buzzword with numerous connotations over the past years, smart cities concept represents a paradigm shift in urban development towards technology and innovation. This vision relies on Internet of Things (IoT), in other words, networks that extend internet connectivity to a diverse range of devices and everyday things that utilize embedded technology to communicate and interact with the external environment. Furthermore, it is frequently associated with practices exploiting ubiquitous feedback mechanisms to engage the users into the management and planning of our cities (Mitchell et al., 2013). Understanding the potentials and the evolution of these are critical to future of urban design and planning.

In this regard, the concept of “ubiquitous spaces” developed upon Weiser’s (1991) vision of ubiquitous computing is an interesting framework to discuss the future practices for the making of urban-architectural spaces. The envisioned characteristics of ubiquitous spaces and their potentials to accommodate the novel urban and architectural design practices can be summarized as (Buxton, 2006; Abowd et al., 1998, p. 2; Weiser et al., 1999):

- Noninvasive capturing of everyday experiences,
- Ubiquitous interactions with the users through gesture and touch driven sensors,
- Networked communication and collaboration,
- Ubiquitous access and manipulation of multiple forms of information,
- Rapid access to past experiences,
- Effective interactive visualization of the information, and
- Contextualization of information.

Capturing of everyday experiences of users in a specific space is essential for any architect or urban designer to understand it better. William H. Whyte is one of the most well-known urban designers to demonstrate the potentials of such practices (Whyte, 1980). In his quintessential research “Street Life” he made in-depth observations using hidden movie cameras and analyzed the interactions between the people and their behaviors at plazas in New York. This research enabled Whyte to identify a number of key factors for the design of plazas which were used in the redesign of Bryant Park. During the capturing of the everyday life, noninvasiveness was an essential strategy to ensure the quality of the observations and respecting the privacy of the users. The technological possibilities were limited at the time of his research and the observations spanned a limited timeframe. However, the results were remarkable. From this perspective, the benefits of capturing everyday experiences of the users in urban spaces are quite clear. Observations with longer time span and better precision can provide valuable information to learn from and enable the designers to make informed decisions.

Another essential characteristic of ubiquitous spaces is their interactivity. This vision goes beyond the traditional understanding of spaces as static structures. Ubiquitous spaces typically involve the use of gesture and touch-driven sensors to facilitate interactions and enable access to and manipulation of multiple forms of information. This opens up novel possibilities for urban and architectural spaces to perform as interfaces between the users and networked communication and collaboration systems. Spaces become canvases for effective interactive visualization of the information and enable its contextualization. The users access information without the need for invasive devices that obstruct their everyday lives.

Several design research studies experimented with the possibilities introduced above (reviewed in Section 2.3). However, the potentials of the “higher levels of information processing” in networked urban environments are underexplored from a designer perspective (Shepard, 2011, p. 11). In this sense, based on the above, the aim of this study is to envision design approaches for creating ubiquitous interactive spaces which can help the ordinary users to handle the increasing complexity of collective urban spaces and empower them to shape and reshape their living environments. The focus will be on addressing the complexity of planning and appropriation of shared spaces by its users as a never-ending self-organizing activity. Considering various scales of urban form and infrastructure, this chapter will discuss the “affordances” (Gibson, 1986) of networked sentient technologies to facilitate bottom-up change in the making of these future collective urban spaces.

The research questions to be explored are:

1. How can we empower the ordinary people to make and remake their urban spaces through design?
2. What are the action possibilities latent in ubiquitous spaces in relation to their users and capabilities?
3. What are the possible future roles of the architect/urban designers in this process?

These questions will be addressed through a case study of archetypical and contemporary practices which involves the extraction of key design strategies, technologies and ways of translating these into spaces (Sections 2.1 and 2.2). In the second part, these will be elaborated further in the context of co-housing to establish a framework for a future design (Section 3.1). This section will be followed by the translation of these strategies into an urban-architectural design of a real-world case: the shared collective space of the first co-housing unit supported by the municipality of Ghent (Section 3.2). The last section will cover structured reflections from the design experience, lessons learned from the feedback of the residents and action possibilities of the design product (Section 4).

2. BACKGROUND

Research efforts for embedding computation into the built environment have a long history of interdisciplinary collaboration. During the last five decades, a significant number of researchers, engineers, designers, architects and artists explored alternative ways to combine spaces and computational technologies with the aim of enabling interactions between citizens, the buildings, and our cities.

Among those, it is possible to spot archetypes or experimental architectures which introduced original ideas that served as well-known precedents to build upon. The conceptual proposals of the Archigram “community” in the 1960s such as the Computer City by Dennis Crompton and the cybernetic Fun Palace by Cedric Price were significant cases which were never realized but inspired the future generations and triggered various projects. Today, these archetypes are still frequently referenced as progressive cases.

In parallel to these, several architects developed radical ways to enable the users to participate in the making and re-making of their living spaces. In *Supports: An Alternative to Mass Housing* (1961-Dutch version) John Habraken introduced the idea of separating the “support” infrastructure from the “infill” to promote open-ended and bottom-up spatial (re)configurations. Through this method, he revealed the affordances of superstructures for empowering the users to build and customize their dwelling. This idea can be clearly recognized in the works of the members of the Archigram Group as an overarching theme.

During the same years, another pioneer in this emerging field was Lucien Kroll. Involving the future users into the design process, he developed the student housing of the Medical Faculty of the Catholic University of Louvain in Brussels. Kroll used a modified version of the modular system of Habraken (SAR) and movable building elements as a basis for enabling the users to reshape their environments. Realized between 1970 and 1974 in Brussels, Belgium this building still stands as a frozen beacon of participatory and adaptive design.

These projects are clear initial attempts at understanding and designing urban and architectural spaces as dynamic structures. In all cases architects aimed at facilitating interactions between the users and spaces during the design process (involving the users, in the making of these spaces) as well as through the design product (reconfigurable building elements) leading to the idea of a dynamic building program which can be modified by the users as a response to everyday needs.

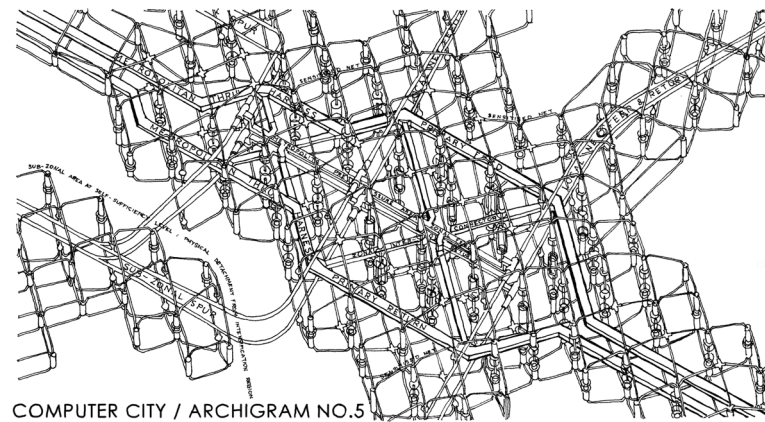
In the following part, Section 2.1, these archetypes will be briefly reviewed with the aim of revealing the implicit strategies (and micro-tactics) pursued by the designers for creating them. Furthermore, their relation to contemporary cases will be discussed in Section 2.2, leading to a synthesis of these strategies and tactics to draw future design directions.

2.1 Archetypes

As introduced above 1960s was marked by the emergence of several experimental projects which brought ground-breaking design perspectives to urban and architectural design. The most notable embodiment of these were the speculative works of Archigram Group of the Architectural Association based in London which can be considered as clear cases of designer research for the rethinking of the relations between technologies, (infra)structures, users, and cities. This group produced iconic “paper” projects for thirteen years and organized several exhibitions until 1974.

Among those, the Computer City project by Dennis Crompton is one of the interesting and relevant cases (Figure 1).

Figure 1. The Computer City by Crompton (1964, p. 13) published in Archigram Magazine Issue No. 5



In this proposal, Crompton (1964, p. 13) did not illustrate any habitable structures in a traditional sense. Instead, he imagined a city for 100.000 people in which architectural/urban program and the computer program were thought interchangeably as an attempt to rethink the relations between space and computation. The conceptual design speculated with a sense of infrastructural order as a representation of possible technologies for a city-system. Crompton (1964, p. 13) envisioned Computer City as a place where the activities of the society take place within a balanced network of forces which naturally interact to form a continuous chain of change. A “sensitized net” senses the changes of activity, the sensory devices respond and feedback information. These are then fed to a computer (conceived as identical to the space itself) which provides a relevant immediate response.

These ideas and order were developed through a diagram, a circuit board like structure that hosted a network of electronic sensors through which invisible flows of electricity and information circulated. This structure sensed the changes in the daily rhythm of a city and responded to these changes (Cabral and Cláudia, 2005). In this sense, the Computer City was a sensitized network capable of detecting changes of activity through sensory devices which respond and provide feedback information to “program correlators”. Then these correlators would readjust the architectural/urban program (through a software program) triggering a never-ending cycle of making and re-making of spaces through limitless possibilities of spatial reconfiguration.

The second case to be reviewed in this section is the Fun Palace by Cedric Price (1961-1970). The preliminary version of this project was published in the same year as the Computer City but in a different issue (Archigram Magazine No. 4). It involved the design of an informal and dynamic entertainment center for the working class. The extraordinary nature of the project came from the wide range of interdisciplinary contributions of Joan Littlewood (performance), Gordon Pask (cybernetics), Buckminster Fuller (structural design), Yehudi Menuhin (symphonic music) and Reyner Banham (architectural theory) (Lobsinger, 2000).

The project aimed at fusing information and communications technologies and industrial building principles “to produce a machine capable of adapting to the needs of users” (Price, 1965). Cedric Price adopted Le Corbusier’s metaphor of architecture as a machine-to-live-in and developed it further. In this sense, the project was an attempt to explore improvisational architecture with the means of cybernetics and information technologies (Mathews, 2006). It did not have a fixed floor plan and intended to

“encourage random movement and variable activities” (Lobsinger, 2000). The building was conceived to be super-functional and adapt to the people’s needs in a sustainable manner (Figure 2 on the left).

During the design process, several practices were proposed by Pask for the cybernetic regulation of day-to-day activities (Mathews, 2006). In this sense, Fun Palace was meant to be an ongoing conversation between the building and its users: “an assemblage of interactive systems of interaction”. In line with these cybernetic principles, Gordon Pask designed an apparatus to collect feedback from the users (Figure 2 on the right). The proposed tool was a physical communication system which he planned to be used informally in one of the theaters to accommodate an invited audience (Pask, 1969). The audience would be responding to a variety of activities using this tool and would be able to transform the theater based on their preferences. Through this exercise, Gordon Pask questioned the role of the users and explored novel ways of participation in an open-ended and performative manner.

The third and the last case reviewed in this section is La Maison Médicale - the Medical Faculty Student Housing of the Catholic University of Louvain (Figure 3). This project was initiated when the University decided to move its Medical Faculty to Brussels. In this design, the architect Lucien Kroll

Figure 2. Fun Palace (left) and the diagram for a cybernetics theater (right) by Gordon Pask (1964)

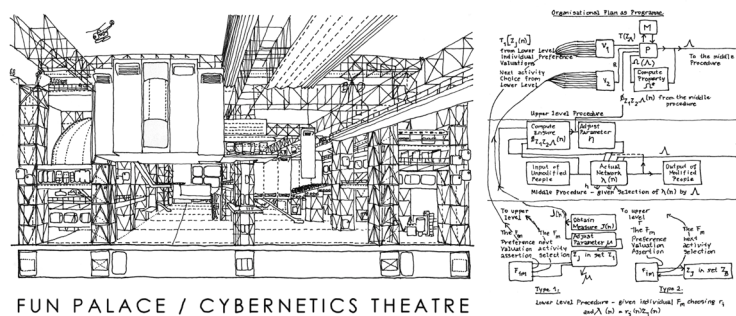


Figure 3. A detail from the façade design of the Medical Faculty Student Housing of the Catholic University of Louvain by Lucien Kroll.



intended to create an open design process, “an action open to new necessities and to decisions that are always provisional and incomplete” (Kroll, 1987). He developed a design with a hypothetically removable infill: demountable window frames, moveable partitions, and prefabricated sanitary units. According to the principles of co-habitation, the infill could be torn down by the users, which encouraged them to take initiative in planning and re-planning their environments. The plan would always be incomplete.

In his book “Architecture of Complexity”, Kroll (1987) reserved a whole chapter to the relations between computers and architectural design. He revealed that -in close contact with the users- he employed various methods to create diversity and differentiation. This involved an electronic library of components that can be combined according to user needs (Kroll, 1987). He stressed the importance of open-endedness and heavily criticized the inflexible artificial intelligence practices of the time which led to self-contained, closed and repetitive results. In contrast, Kroll envisioned the drafting software as a potential tool that allows open-endedness through which the architectural product and the social relationships can be involved in the design and manufacturing process. However, in the early 1970s the communication technologies were not developed enough to realize the social part of the potential fully.

Overall the most interesting aspect of this project were the ways in which the users were empowered to participate: a) by engaging in the design process and b) through the participation opportunities provided by the architectural design per se (movable-modular partitions and changeable façade elements).

In conclusion, all three of the projects referenced above reframed and rethought architecture: as a form of communication (for user representation), as an interface and as flows of networked information. They have attempted to capture everyday experiences; enabled different forms of interactions with the users; envisioned networked communication and collaboration, accommodated access and manipulation of information and foresaw forms of interactive visualizations and contextualization (Table 1). Due to the technological limitations of the time period, these were rather incomplete, ambiguous and conceptual. From a design perspective, these qualities make them inspirational and exciting today.

Table 1. Analysis of the archetypical projects in relation to the characteristics of ubiquitous spaces

Characteristics	Computer City (Unrealized Concept)	Fun Palace (Unrealized Project)	La Maison Médicale (Realized Project)
Noninvasive Capturing of Everyday Experiences	natural interactions form a continuous chain of change	through user interactions: reorganizing the space	in and through architectural form
Interactions with the Users through Sensors	a network of electronic sensors	human and electronic sensors	human sensors
Networked Communication and Collaboration	invisible flows of information	making and re-making of the space; theatrical performances	traditional meetings, architectural elements
Access to and Manipulation of Multiple Forms of Information	sensitized net detects activity, sensory devices feed information	cybernetic feedback apparatus	element library, SAR modules
Rapid Access to Past Experiences	program correlators	spatial reconfiguration and performances	spatial user reconfiguration
Effective Interactive Visualization of Information	the city is the visualization of information itself	the building takes shape according to feedback, (space as visualization)	pre-design, traditional meetings, three-dimensional CUD
Contextualization of Information	information is the context	in and through architectural form	in and through architectural form

Besides the commonalities, Table 1 also reveals the differences in design approaches between the cases. For instance, Cedric Price's idea of adaptability is quite unique. The design concept provides solid suggestions for an integrated system of ICT systems facilitating adaptation, ranging from the interaction devices to rotating escalators, movable rooms, and performance spaces. On the other hand, Kroll's design concept of adaptability is based on provisional use and incompleteness. In this regard, his design approach is rather archaic and recalling historical vernacular architecture cases which evolved for centuries through incremental user interventions. In contrast, when compared to Fun Palace and Maison Médicale, Computer City concept is original for the early prospects of real-time self-regulation through immediate feedback and response.

2.2 Contemporary Cases and Sentient Technologies

During the last two decades, ubiquitous and pervasive computing technologies -initially a subject of inquiry for human-computer interaction (HCI) researchers- started to appear in everyday life as building systems and public infrastructures (Greenfield, 2010). The worlds of design and planning have witnessed the emergence of the theories on and technologies of smart buildings, smart furniture, smart clothing, smart glasses, smart street signs and most importantly smart cities.

Coined in 1992, the phrase "smart city" was first used to describe a paradigm shift in urban development towards technology, innovation and globalization (Schaffers et al., 2011, p. 433). Over the past few years, this concept is used with connotations to numerous ideas, issues, techniques and strategies of different nature and scale: innovation and creativity, climate change, efficient buildings, renewable power, easy transport, clean water, urban health (Swanson, 2012). In all of these efforts, it is possible to trace at least two main common points (Mitchell et al., 2013): using information and communications technologies (ICTs) and the Internet to address urban challenges. The specific practices frequently referenced in this context can be summarized as: urban environment monitoring, large-scale and interconnected sensing, data analytics and information visualization, interconnected sensing and the "Internet of Things" sharing information across platforms through a unified framework and developing novel models of planning and governance incorporating the above.

In the following part of the study specific projects around the world will be reviewed with a focus on their variant approaches for coupling the concepts of ubiquitous computing technologies and sentient urban spaces. The first one is Neural Network House, a project developed by Michael Mozer and his team. This project aimed at creating a system called ACHE (adaptive control of home environments) for a house which can observe and learn the everyday practices of users through sensors, self-regulate the comfort systems in the house accordingly and in this way, accommodate their needs. Based on the principles of trained Neural Networks this system was designed to predict numerous variables such as the location of the users, their patterns of electricity and water usage. While doing executing these tasks, it also aimed at conserving energy and minimizing the energy costs.

The most interesting aspect of the Neural Network House is that ACHE system was integrated into a renovated historical building which hardly manifested its potentials. It had only a few interfaces and aimed to avoid invasive interactions. In this context, the thought-provoking part of this project was not the architectural design but rather the innovative design of the regulation methods which completely altered the traditional relation between space and its users.

The second case to review is Amphibious Architecture by XDesign Environmental Health Clinic, a commissioned installation for the Toward the Sentient City exhibition in New York, 2009. The main goal of the project was to raise awareness by evoking curiosity on waterways and the invisible biodiversity hidden underneath. It utilized a grid structure of buoys equipped with sensors which were submerged under the water coupled with LED lights above. These sensors monitored water quality, the fishes (motion sensor) and naturally the waves and ripples. People were able to send responses in the form of SMSs which activated the LEDs on the buoys; triggering a cyclical feedback between the ecosystem and humans (Figure 4) (Benjamin et al., 2011, p. 54).

In Amphibious Architecture installation, similar to the Computer City project, the space is designed to emerge as a result of information flows, a real-time visualization of the complex relations between underwater life and human. A unique aspect of Amphibious Architecture was the conception and treatment of fish, waterways and humans as a part of the shared environment: the recognition of ecology as a participant in urban life. The role and position of the designers in this process was quite disruptive. In contrast to traditional conservationist approaches to urban environments it evoked participation and engagement through sentient technologies. Most importantly, the installation established a cycle of second order cybernetics: observers (humans) observe the observers (sensors) observing other observers (fish) which observe the feedback LEDs driven by the interaction between the three. A possible adaptation of the fish, humans or sensors has not been rigorously documented; which would even elevate the relation to the third order.

The last case to be discussed in this chapter is Bell Laboratories-Alcatel Lucent's Quantified Workplace System implemented in two offices of a research organization in Europe in 2014 (Mathur et al., 2015).

In this study, different workplace metrics were captured through public terminals as well as personal devices, and the associated data services provided to the users. This research brought up numerous questions on designing workplaces with embedded real-time monitoring systems. Two different aspects were quantified by the researchers: physical metrics of the office environment and the employees. The sensors collected metrics such as indoor location, self-reported mood, self-reported physical activities and environment metrics such as noise, color of clothes and air quality (CO₂ levels) (Mathur et al., 2015). Additionally, participatory feedback was collected in two different ways: through a mobile application and anonymously through a public placed input interface.

Figure 4. Amphibious Architecture by XDesign Environmental Health Clinic, Installation in New York 2009 Photo: Chris Woebken



The most interesting result of the Quantified Workplace practice was methodological. First, due to the device heterogeneity, mobile-based sensing was too complex to handle. Some users were left out due to software incompatibility, and this affected trust negatively. Second and most important, the employees expressed that they perceived the output of the system as a reflection on their workplace; thus changed their behavior. In addition to the above, Quantified Workplace System revealed several trajectories relating to architectural and urban design. Through the analysis of user movements in space and appropriation patterns by real-time visualizations and heat maps, it was possible to map the ways in which an office building was used by the employees and their communication patterns; revealing the informal communities in different workplaces. Another inspiring suggestion of the system was the possible combination of this information with energy and weather data, leading to a more efficient use of resources. These kinds of applications are potentially valuable to the architects and urban designers as means to post-occupancy evaluation.

In conclusion, the three different practices introduced in this section reflect different ways to understand our spaces, capture and visualize everyday experiences of the users leading to novel modes of networked communication and collaboration a) in and 2) through design (Table 2).

3. DESIGN STRATEGIES TO FACILITATE THE SELF-ORGANIZATION OF COLLECTIVE URBAN SPACES

The design-explorative part of this study section addresses the complex problem of planning and appropriation of a shared space in a co-housing unit currently under construction in Ghent, Belgium.

This building is located in one of the super-diverse neighborhoods in the city. All of the co-housing residents are of Belgian origin, but their future neighbors are mostly immigrants. In this sense, in order to assure the integration of the unit, it was necessary to enable a dialogue between these social realities through design.

Table 2. Analysis of the archetypical projects in relation to the characteristics of ubiquitous spaces

Characteristics	Neural Network House (Realized System)	Amphibious Architecture (Installation)	Quantified Workplace (Realized System)
Noninvasive Capturing of Everyday Experiences	numerous sensors including heat, temperature, optical proximity	buoys with sensors, water quality, the fishes (motion sensor) and the waves	smart mobile devices: location, self-reported mood and physical activity
Interactions with the Users through Sensors	location sensing, prediction, regulation of comfort systems	real-time sensing of underwater life	sensors of the mobile devices, human sensors
Networked Communication and Collaboration	web-based dashboard	feedback through SMS	mobile feedback interfaces
Access to and Manipulation of Multiple Forms of Information	hard data, a neural net, look up tables	real-time LED lights	dashboard
Rapid Access to Past Experiences	web-based database	none	web-based database
Effective Interactive Visualization of Information	web-based dashboard	the space itself is the visualization of the information	complex dashboard graphics
Contextualization of Information	home	dynamic, over the waterways	two office spaces

In order to address this challenge, a multi-stage design method has been put into action. The first stage involved background research through which several key success factors were elicited from the cases reviewed in Sections 2.1 and 2.2. As a result, it was clear that sustainable and informed bottom-up planning requires the development of open-ended systems which enable user organization, feedback, and intervention in a self-regulatory, indeterminate manner and without a limited end-state. Second, for the appropriate regulation of user participation, the variety in the regulator must be equal to or greater than the variety in the system being regulated (Ashby, 1958). Therefore, the proposed model should not be closed but open to the external input of different actors at various stages. Third, the framework should embrace circular relationships between cause and effect, in other words, reflexivity.

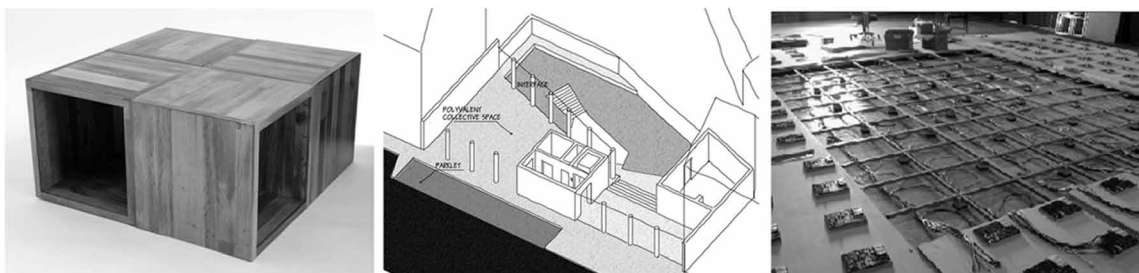
The second stage was the analysis of the urban context at the neighborhood level, understanding the principles and typologies of co-housing and the spatial aspects of the building plot. GIS mapping of the socio-economic indicators revealed the challenging location of the project in a low-income and super-diverse quarter. Furthermore, it became evident that the shared space had to be on the ground floor level due to several complex restrictions of the project and the plot.

The third stage involved elicitation of requirements and needs of the users in a participatory manner. This was achieved through several interactive meetings with real users. During these meetings, the role of the architect was to uncover the possibilities and illustrate them to the users in an understandable format. Discussions on these allowed to set certain goal measures: 1) accommodating different levels of privacy through dynamic façade elements 2) enabling the users to reconfigure the space through flexible and modular furniture 3) the use of non-invasive sensors and visualizations to inform the users about real-time configuration and appropriation modes of the shared space.

The fourth stage was the development of a solid proposal in line with the background research, addressing the key success factors, analysis results and the goal measures and requirements. The suggested proposal involved a design concept that incorporates the following design ideas (Figure 5):

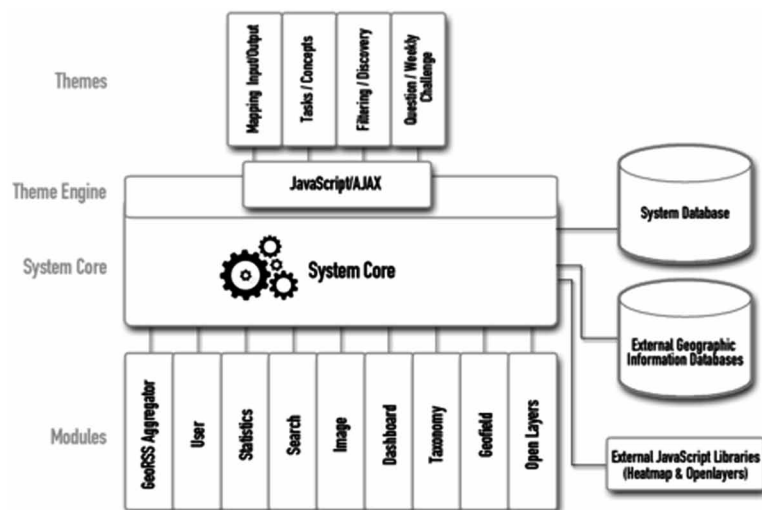
- **Mobile and Modular Urban-Architectural Furniture:** Stackable self-made modules built by the inhabitants enable the reconfiguration of space following the principles of self-organization. The water resilient quality of the wood construction facilitates flexible and adaptive use and aims at embracing spontaneity. The lightness of the modules (hollowness) is a key aspect in empowering users of all ages to reconfigure the space. By stacking the modules, it is possible to create tribune structures to be used for events such as arts performances.

Figure 5. Mobile and modular urban-architectural furniture (on the left), the collective polyvalent space (in the middle), the floating floor system (on the right)



- **A Collective Polyvalent Space which can be Opened Up to the Whole Neighborhood:** For larger scale collective use, incorporating flexible façade elements (mobile accordion doors) allows regulation of different levels of privacy. The first level is to relocate furniture modules to the parklet in front of the co-housing unit to enable interactions with the passersby. The second level involves opening up the door on the front façade, creating a semi-covered space for events such as exhibitions, and performances. The third and the less frequently used level gives access to the backyard, facilitating the organization of more inclusive events.
- **A Floating Floor System with Networked Pressure Sensing Units:** The system registers the applied forces and maps the appropriation of space at the ground level. This low-cost system is based on the technological implementations of (Srinivasan, Birchfield, Qian et al., 2008) (Rangarajan et al., 2007) utilizing networked pressure sensing units (48cm x 42 cm) arranged in a matrix form. The material cost of the module is estimated at 16 USD per square meter by the developers, excluding the craftsmanship for installation, testing and maintenance.
- **A Web Server and a Geoweb 2.0 Platform:** These collect data from the sensors, convert and feed the data through an open-source content management platform in GeoRSS format. A dynamic visualization module that combines OpenLayers and heat maps libraries and Google Maps API renders a dynamic and geolocated plan of the space (Figure 6). This framework is based on the Geoweb 2.0 platform implemented by the first author and used in various planning practices and urban design studios in Brussels (Pak and Verbeke, 2014). It enables geolocation-based communication among the users through the open-source CMS accessible via mobile and desktop computers.

Figure 6. The Geoweb 2.0 platform to be used to combine OpenLayers and heat maps libraries and Google Maps API for rendering a dynamic and geolocated plan of the space



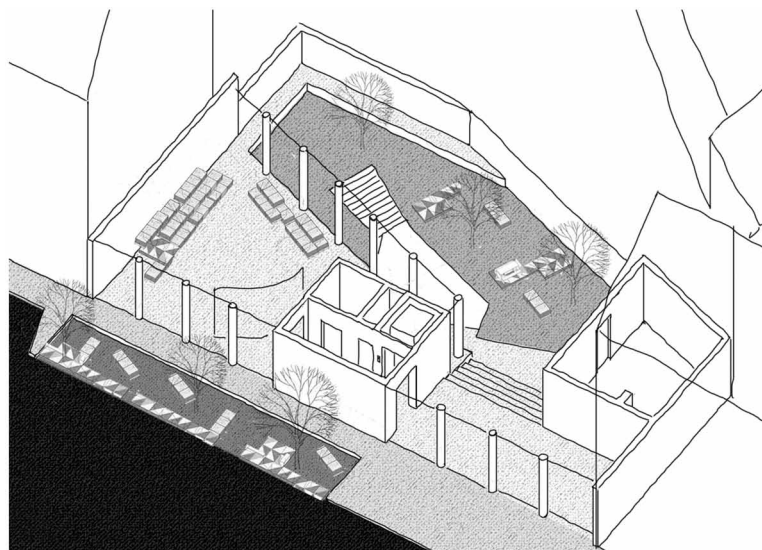
The resulting concept is a sentient collective space (Figure 7) that aims to empower the users to plan and re-plan their collective living environments and promote novel social encounters by the following action possibilities:

- User configurable mobile urban-architectural elements including separators, façade components, and furniture.
- A real-time online plan through which the users can get informed about the everyday uses of the collective space and negotiate future uses.
- Storage and access to past configurations and appropriation of the space for decision-making.
- This concept has been presented to the future users of the collective space in November 2015 as a means to involve them in the development process. Overall, the feedback regarding the architectural principles was positive. At the time of writing this article, the design process was still ongoing, and the first action was planned to start with the parklet, right after the completion of the main structure.

4. CONCLUSION AND FUTURE DIRECTIONS

In this chapter various design cases incorporating ubiquitous computing and sentient technologies are reviewed. These different practices reflected different ways to understand our spaces, capture and visualize everyday experiences of the users and novel methods to integrate them into the design processes. They aimed at empowering ordinary people to make and remake their urban spaces. Section 2.1 and Section 2.2 revealed alternative design strategies for incorporating and multiplying these possibilities.

Figure 7. The conceptual design of a polyvalent collective space with self-made and self-organized modular furniture and a sensing floor with hidden networked pressure sensing units.

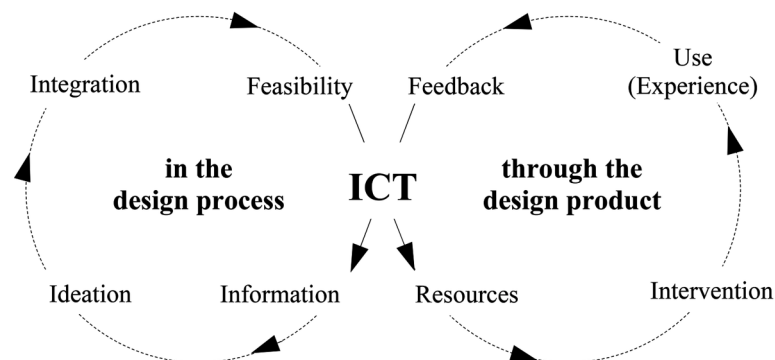


As a result of the analysis of the cases, two modes of empowerment through the use of technologies became evident a) empowerment in design and b) empowerment through design. These two modes were significant in the ways they enabled the users and designs to co-produce spaces in a sustainable and participatory manner. In a nutshell, technological empowerment in the design process involves practices that allowed users to contribute to the overlapping phases of the planning and decision-making. These practices were realized by enabling access and manipulation of multiple forms of information including past cases, effective interactive visualizations of information and contextualization through mapping. In contrast, the second mode enables technological empowerment through the design product. It involves the practices of facilitating noninvasive capturing of everyday experiences using sensors and enabling networked communication and collaboration.

As discussed during the review of various cases, these modes can be fused into two cycles of cooperation in which the output of one process is transformed by a second process and transferred to the other one as input. Eventually, through these cycles, this integrated practice can potentially lead to a continuous reflexive and adaptive making of spaces. In this conceptual frame, ICT tools fuse two cycles of cooperation in which the output of one process is transformed by a second process and transferred to the other one as input (Figure 8). The first cycle (Figure 8, on the left) involves a type of social knowledge construction, building social capital. This capital is transferred to the second cycle (Figure 8, on the right) through which the users gather resources, take action, accumulate experience and give feedback to the first cycle. This open-ended process involves several steps which can be supported by different types of novel practices accessible today (such as crowdsourcing, crowdfunding, and responsive structures).

In addition to the conclusions above, in Section 3, several key principles were distilled for guiding future practices: incomplete, dynamic architectural program, continuous representation of the user needs, incorporation of user variety and differences, development of design rules or systems that “regulate” the building in an open-ended way, self-organization orchestrated by the designer and the technologies, and embracing spontaneity in use. Following these principles, the conceptual design of a sentient space in Ghent was revealed as a means to demonstrate action possibilities latent in ubiquitous spaces. During the interactions with the future users of the co-housing complex, various challenges emerged. These challenges can be grouped under four topics:

Figure 8. Empowerment of the users through ICT in the design process and the design product



- **Legal Limitations:** The planning regulations are insufficient to support the dynamic cases with open programs introduced above. The municipality follows a slow process of evaluation which creates difficulty in creating an open program.
- **Privacy:** Users were quite sensitive about their privacy. Introduced design involves the collection of private data. Therefore, users were concerned if this information will be treated sensibly and carefully or not.
- **Trust:** Trust was a key factor in our dialogue which clearly affected participation levels of each participant. The perceived trustworthiness was closely tied to the inclusion of the users to the goal-setting as well as the treatment of privacy matters.
- **Affordability:** Although the floating floor system with networked pressure sensing units was significantly cheaper than the existing commercial alternatives, it increased the overall cost of the proposed polyvalent space.

These challenges are planned to be addressed through tactics such as: applying for temporary licenses for the use of urban spaces (the parklet), anonymization of the user data to help protection of privacy, continuous involvement of the users in the goal-setting and feedback processes through reflection meetings and getting integrated project funding to support the implementation process.

As a future direction, the proposed design can be extended as a diversified network and repeated for other collective spaces in the neighborhood. This network can incorporate various collective spaces and explore the possibility of the dynamic map at a larger scale (the neighborhood level). This would be a sustainable monitoring system that joins the scattered knowledge on rapidly changing social needs in various neighborhood infrastructures. Furthermore, by coupling this data with environmental data and pattern recognition techniques, it would be possible to provide real-time energy simulation feedback and enable the automatic recognition of spatial configuration patterns which can be useful for design optimization and regulation.

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Chapter 10

Social Media Geographic Information: The Community Perspective in Planning Knowledge

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ABSTRACT

Since last decade, advances in the Information and Communication Technology (ICT) are increasingly enabling the voluntary sharing of user generated contents. Among different emerging digital resources, georeferenced multimedia data publicly shared through social media platforms, or Social Media Geographic Information is starting to stand out in quantity and value as data resource. In spatial planning, where the majority of information required to support analysis, design, and decision-making is inherently spatial in nature, SMGI may foster notable innovations in methodologies and practices, allowing the integration of both experiential and professional knowledge on places, events and ambient. However, this hypothesis should be carefully tested. With the above premises, this chapter more specifically concerns the concept of Social Media Geographic Information, arguing that it may represent an unprecedented resource for expressing pluralism in such domains as spatial planning where it may convey the community collective preferences contributing to enrich knowledge for decision-making.

INTRODUCTION

An unprecedented wealth of digital Geographic Information (GI) is made available nowadays to spatial planners for supporting analysis, design, and decision-making. This trend may foster important innovations in urban and regional planning practices, for the information used in supporting analysis, design and decision-making is inherently spatial in nature.

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Since the early 1960s, Geographic Information Systems (GIS) started to be introduced as support in spatial government and planning, replacing more traditional analogue data and maps. Recent approaches to spatial planning introduce the concept of Geodesign, emphasizing the importance of carrying on design and decision-making processes informed by the knowledge of the local territorial context. As argued by Steinitz (2012), there is no such profession as the Geodesigner, rather a Geodesign process is carried out through collaboration among different experts coming from the Geographic (Information) Sciences and from the design disciplines, together with stakeholders and other actors from the local communities, or the people of the place. Hence, considering stakeholders' involvement, coupled with the possibility to elicit local communities' knowledge in supporting planning processes, may represent a significant implication for future research in the field of spatial planning. In the era of Information and Communication Technology (ICT), such an approach is currently enabled thanks to development both in authoritative and volunteered sources of geographic information.

On the one hand, the implementation and the widespread diffusion of Spatial Data Infrastructures (SDIs) are starting to offer planners the access to a wealth of digital official large scale spatial data layers, produced and maintained by public or private organizations for a variety of institutional or business purposes. This process is enabling the evolution from analogue cartographic analysis to digital geoprocessing in the representation and analysis of territorial dynamics, as well as, in the assessment of environmental impacts of design alternatives. This phenomenon is remarkably notable in Europe, where the implementation of the Directive 2007/02/CE, establishing a shared INfrastructure for SPatial InfoRmation (INSPIRE), fostered the development of SDIs in Member States and regions, enabling the public access and reuse of available Authoritative Geographic Information (A-GI) according to common data, technology, and policy standards. Hence, SDIs may provide positive impacts for public administrations, developers and planning practitioners, and they are slowly bringing innovation into the planning practices (Campagna and Craglia, 2012).

On the other hand, advances in connectivity, geobrowsers and widespread diffusion of GPS-equipped handheld devices enabled citizens acting as sensors (Goodchild, 2007) to provide Volunteered Geographic Information (VGI). Open Street Map is one successful example of crowdsourced creation of a comprehensive open spatial dataset as a high quality alternative to more traditional official or commercial sources. However, only a fraction of available VGI is purposefully produced and contributed, while an even larger share is made available often as unaware results of the use of social media on web and mobile apps. Indeed, among different emerging digital resources, georeferenced multimedia data publicly shared through social media platforms (Sui and Goodchild, 2011), or Social Media Geographic Information (SMGI) (Campagna, 2014), for the impetuous modes of production, is starting to stand out in quantity, featuring a Big Data nature. The mutual integration of these information sources may substantially improve the understanding of environmental and social ecosystems, and of people perceptions, insights, and needs.

In the light of these considerations, the authors present a critical review of their research findings on the integrated use of A-GI, VGI and SMGI in the domain of spatial planning. In the next section, an overview on the diffusion process of SDIs and VGI is given, providing a comparative critical assessment, which outlines differences in the production and use of these GI resources. Moreover, an explanation of the differences between VGI and the subset of SMGI, highlighting the peculiarity of SMGI data model and the opportunities for spatial planning, is provided.

Afterwards, the SMGI analytical framework, developed by the authors, is introduced focusing both on theoretical and practical perspectives for the use of SMGI in spatial planning. Several analytical methods, which may be used to elicit useful knowledge from this kind of information, are described. In addition, a tool called Spatext that is designed by the authors to ease the integrated collection, management and analysis of SMGI, is presented.

In order to demonstrate the capabilities and opportunities of SMGI as complementary source of information to A-GI and to test the validity of the SMGI analytics framework in practice, several case studies, concerning different issues, which are related to spatial planning, are presented. Then, the opportunities of SMGI as an enabling factor for public participation are discussed. Finally, a reflection on the impacts and results concludes the argumentation on the SMGI relevance for spatial planning analysis, design and decision making. Overall, the chapter aims at demonstrating that, despite existing limitations and risks, SMGI may substantially improve our understanding of communities' knowledge and perceptions, as well as, of the underlying social processes in knowledge building and decision-making.

Sources of Digital Geographic Information

The origin of the first generation SDIs dates back to the early 1990s, when in the United States of America, the President Clinton's Executive Order 12906 defined the National SDI as an infrastructure comprising "technology, policies, standards, and human resources necessary to acquire, store, distribute, and improve utilization of geospatial data" with the aim of achieving more sustainable development processes. Since the last decade, SDIs are facing widespread diffusion and development in many countries worldwide. Most notably, the implementation of INSPIRE (Directive 02/2007/EC) establishes the legal framework for setting up and operating an Infrastructure for Spatial Information in the European Community, leading to the development of National and Regional SDIs in the Member States. The objective is easing the spatial data integration and sharing, as well as, improving decision-making for sustainable development. In order to achieve these objectives, common specifications are given for 34 spatial data themes, to be made publicly available through geo-portals, often at no costs. Geo-portals are the most popular and extensively used technology that leads the implementation of local, regional and national point of access for SDIs. Maguire and Longley (2005) define a geoportal as "a World Wide Web gateway that organizes content and services such as directories, search tools, community information, support resources, data and applications".

Many of the INSPIRE data themes, such as administrative units, land-use, or buildings, to name few, are of great relevance in spatial planning. Hence, planning professionals may take advantage of unprecedented opportunities to analyze and understand territorial system dynamics. In the last decade, several regional governments across Europe already started to build their Regional SDIs, and in many cases the development process can be considered already advanced. As an example, in some Italian Regions, such as Lombardy and Sardinia, the spatial data and services of the regional SDIs are enabling the application of policy measures, which foster the use of GIS in the Municipal Master Plans' (MMPs) implementation (Campagna and Craglia, 2012). The evolution in the professional practices can be considered still at the early stage, but now the conditions seems favorable for a wider Geodesign methods' diffusion to be realized (Steinitz, 2012).

In parallel in the last decade or less, advances in geospatial positioning, Web mapping, cellular communications and wiki-based collaboration technologies have surpassed the original visions of the architects of SDIs around the world (Goodchild, 2007; Craglia et al., 2008). As a result of this advances in technologies, more and more people contribute in sharing geographic information on the Internet. At the same time, the scientific community, planners and marketing companies try to create appropriate ways to help users act and provide data on the Internet and to find a way to collect them. It was also proposed to use the term neo-geography to define “geographical techniques and tools used for personal activities or for utilization by a non-expert group of users; not formal nor analytical.” Since 2007 the concept of Volunteered Geographic Information (VGI) became mainstream to indicate the avalanche of directly or indirectly (i.e. through geocoding) georeferenced information which every second is shared on the web by citizens acting as sensors (Goodchild, *ibidem*). VGI may include GI collected by groups of concerned people, or volunteers (e.g. OpenStreetMap and WikiMapia), as well as geo-tagged multimedia (e.g. tweets or pictures on Instagram) collected for personal purposes by web users and publicly shared through social networks. VGI has been proven useful in many application domains such as emergency management, environmental monitoring as well as spatial planning (Poser and Dransch, 2010).

Nevertheless, several hurdles arise in finding suitable practices and procedures to manage the available avalanche of information, although advanced Big Data analysis could represent a suitable solution to extract and manage VGI (Miller, 2010). As a matter of fact, citizen-generated information could give the planning practice valuable insights. On the one hand, qualitative information helps to inform ongoing deliberations regarding design and planning solutions, while, on the other hand, VGI collected and visualized throughout the GIS tools may facilitates a shared reflection on a future vision of a city or a region based on the citizens’ actual vision (Knudsen and Kahila, 2012).

SMGI: Why Social Becomes Special When It Goes Spatial?

In recent years, Social Network Sites (SNSs) and Location-Based Social Networks (LBSNs) have gained huge popularity over a short period of time among millions of users worldwide. Social networks may be considered as the natural evolution of microblogging systems (Vieweg et al., 2010) and may be defined as online communities of people who share common interests and activities spatially located by means of specific web services, which offer several interaction possibilities, ranging from a simple chat toward more complex forms of online communications, such as mobile connectivity, blogging, photo/video sharing and co-creation, modification and sharing of User-Generated Contents (UGCs) (Kietzman, Hermkens, McCarthy et al., 2011). A big part of UGCs also feature spatial (and temporal) references, thus their integration with A-GI may enable a further step towards the next generation of geospatial intelligence in planning.

The spatial dimension is increasingly becoming a fundamental component of many online services, enabling people to share information about their geographic position and their movements with peers. Therefore, the LBSNs appeal to a wide audience is driving geography into daily routines, fostering the convergence of GIS and social media, as argued by Sui and Goodchild (2011), and transforming the Internet in an affordable and potentially boundless information source. The information contributed by the users to SNSs and LBSNs, namely Social Media Geographic Information (SMGI) (Campagna, 2014), may be considered as a special subset of VGI, although the voluntary production and sharing of GI is not the main purpose of the users. SMGI, depending on the production modes, may be actively or passively contributed: applications purposefully created and/or used to collect SMGI in participatory

initiatives originate active SMGI, while SMGI harvested by general purpose social media (e.g. Twitter or Instagram) are passive, and it can be considered UGCs, generically (Campagna, *ibidem*). Notable ethical implications may arise from the social media research, particularly regarding privacy issues, due to the increasing availability of SMGI datasets easing the access to both individual and collective behaviors (Bos et al., 2009). Despite most of the contents are freely accessible through the Internet, many users may be not aware of this opportunity, generating serious issues for data collection and analysis (Ess, 2002).

In the light of the previous considerations, SMGI could be considered a very valuable information source to support design and decision-making in spatial planning. However, a new appropriate analytical model is to be formalized for the datasets peculiarities, which make this type of information different from more traditional A-GI (i.e. spatial data layer from institutional SDIs), with which though it can be integrated for eliciting useful knowledge. Currently, common A-GI vector datasets, which feature geographic and thematic component, are available for download in national or regional SDIs as shape-files or remotely accessible as Web Feature Services (WFS), in many regions in Europe. They can be represented as follows:

$$\text{A-GI} = \langle x, y, z; ai \rangle \quad (1)$$

where the geographic coordinates are represented by x, y, z , and any thematic alphanumeric attribute of the common relational database data types (i.e. text, incl. URLs, numbers, or dates) are specified by ai .

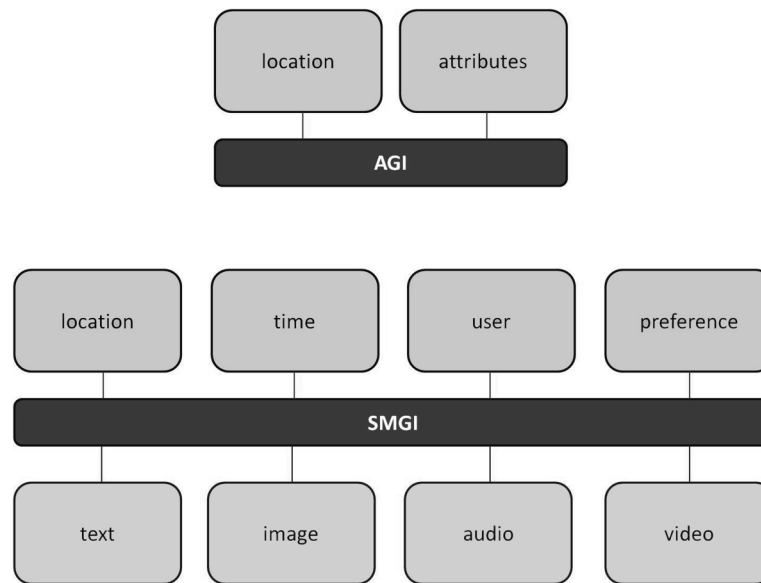
By contrast, SMGI features a richer data model, which includes temporal and multimedia components. Moreover, each piece of information shows a user' dimension combined with a specific identifier, which gives information regarding the user profiles. From the analytical perspective, the latter plays a special semantic role for the user who created and shared the single piece of information, becomes a dimension for analysis. In addition, due to the functioning of the majority of social networks, each piece of SMGI often provides a score expressing agreement by, interest for or popularity among the virtual community. Thus, SMGI can rather be represented as follows:

$$\text{SMGI} = \langle x, y, z; t; u; mi; l \rangle \quad (2)$$

where the temporal dimension, associated to each element of the set, is represented by t , u identifies the user, mi the multimedia content, that, in addition to alphanumeric contents, usually include also images, video, or audio clips, and l the user' preferences, such as the 'likes and dislikes' amount, the number of 'stars', or any other kind of score, which indicates measure of the consensus and it should be treated accordingly in the analysis. Figure 1 summarizes the main features and differences of the A-GI and SMGI data models.

With this in mind, any SMGI analytical framework should integrate traditional spatial analysis with temporal, multimedia, and user' behavioral analyses methods, in order to fully exploit the knowledge potential embedded in data. In order to address the current lack of a formalized analytical framework to collect, manage, and process this information, the findings of several experiences, developed by the authors, are presented in next sections.

Figure 1. A-GI (top) and SMGI (bottom) data models' general framework



The SMGI Analytical Framework: From Collection to Analysis

SMGI platforms can be used either for leisure or for professional purposes, allowing the integration and sharing of all the resulting information streams. Some users may create a project for documenting, with texts or multimedia attributes, their georeferenced travel log and sharing it with friends. At the same time, a local administration may ask the community to report local infrastructure maintenance issues, such as the case of the popular Fixmystreet.com, or to reveal forgotten cultural sites, or to evaluate local landscape values, to mention just few examples. Hence, providing a user-friendly interface may support any kind of spatially focused discourse. Social media platforms can be used to create a dynamic dialogue and monitor people interests about the place on a routine basis; however, when a social network works successfully, a great deal of information starts to accumulate and it may be difficult to extract useful knowledge from the resulting big data avalanche. Computational social science is a new paradigm emerging with the aim of finding new methods and tools to tackle the complexity of big data (Lazer et al., 2009).

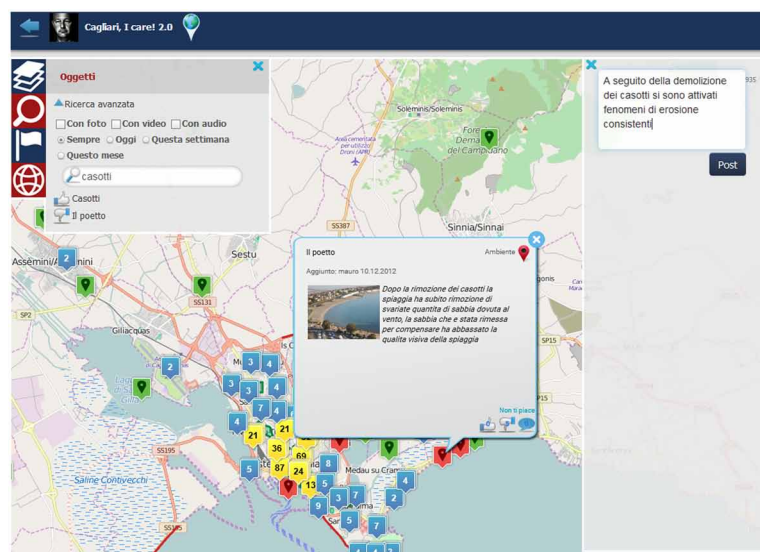
In order to investigate how the opportunities generated by the innovation in social processes granted by new technologies could bring innovation in spatial planning and decision-making, the authors developed in 2011 a web application called “Place, I care!” (PIC!) (Campagna et al., 2012). The results of the first pilots using PIC! were successful for framing a new SMGI analytics and developing the methods and tools presented in the reminder of this work. PIC! was originally designed as a geographic social networking platform to be used in urban and regional planning processes. The idea was to develop a VGI planning support tool for collecting information from concerned citizens about the environmental, physical, and socio-cultural space, and for supporting dialogues about urban issues in a participatory manner. This web application enables each user to easily create her/his own VGI projects in few steps, offering a flexibility that allows implementing a number of use-cases to fit a variety of working settings. While other similar platforms were available on the web during the PIC design’ time, no other was found which would allow creating so many different use-cases, not only to describe individual issues of concern

or appreciation, but also to improve the possibility for participated discussion, thanks to the integration of geo-web tools within a social network paradigm. Data collected with PIC! in different experiments enabled to understand “what and where” the main interests and concerns of the participants were located. Moreover, in PIC! each post can be “Liked/Disliked” and commented by other users supporting the discussion. The more a post got comments or Like/Dislike, the more the topic was considered hot by the interacting community. Nevertheless, the novelty here is that the discussion is georeferenced and visualized in the map. While this model in principles may be not new, it was not implemented with the touch-and-feel and ease-of-use of the social networks app until few years ago. As the number of posts increases it would be always possible both to visualize which topics are important to the community, where they are located and the time of the sharing comment, and to investigate patterns in the developing discourse through spatial analysis and statistics functions. Summarizing, PIC! 1.0 was developed aiming at combining two main requirements: ease of use and availability to all, and robustness, which other geobrowsers could not guarantee to the final user. Figure 2 shows an example of a multimedia post with comments in the PIC! interface.

From an analytical perspective, the first exploratory analyses conducted on the pilots’ results led to framing an integrated analytics framework, called SMGI Analytics, which, thanks to the peculiar SMGI data model, includes:

- Spatial analysis of user’ interests: the high number of georeferenced posts and comments enable to investigate the patterns of user’ interest in space by density and clustering functions. The overlay with topographic A-GI such as administrative boundaries, transport infrastructure, buildings services or public spaces, may offer useful hints to public authorities to understand which places are important for the local communities and how those areas are perceived by them.
- Spatial statistics on user’ preferences: collecting posts by spatial units may enable planners to analyze patterns in user’ interest at different scales. An example is given in the case studies sec-

Figure 2. PIC! Interface and example of multimedia post



tion where the hot-spot analysis is applied at the regional level, in order to study the distribution by municipality of positive user' assessments, investigating why different tourist typologies prefer certain areas or destinations rather than others. In the same case study, the hot-spots, coupled with Spatio-Temporal Textual analysis (see STTx below) and geographically weighted regression analysis (Fotheringham et al., 2002), disclose opportunities for a general comprehension of user' contents and trends at the local scale, eliciting factors which may affect tourists' positive preferences;.

- Multimedia content analysis on texts, images, audios, or videos: this kind of analysis is later discussed in a case study concerning texts analytics. However, it is currently more difficult to automatically extract useful information from images, video or audio. In the case of textual information, many software can be used to apply from simple (e.g. tag clouds) to more advanced (e.g. sentiment analysis) text analysis techniques. These techniques can be easily applied to SMGI subsets, obtained by spatial, temporal or user query (see STTx below);
- Temporal analysis of users' interests: information related to time represents an often available attribute in SMGI, enabling to study when given regional destinations, urban districts, public spaces, or other services are used during the years, the months, the weeks, or the days;
- Combination of two or more of the previous analyses, such as the Spatio-Temporal-Textual Analysis (STTx) which enables to elicit what people discuss in space and time: textual analysis functions can be integrated within GIS application (Campagna, 2014), enabling the application of text analysis techniques to SMGI subset, selected by space and time. Several examples were tested by the authors to analyze the perception of different neighborhoods in the city using Place, I care! data (aforementioned in this section), the judgment of tourists on a destination using Booking.com data, or who is talking about an event of global reach around the world using Twitter and YouTube data (case studies section). In addition, several case studies on the application of STTx into the same areas with different SMGI sources (thus different users) returned similar results, which suggest the need for further research, devoted to better understand the issue of the representativeness of the results;
- User' behavioral analysis: querying SMGI by user enables to study users' behavior in space and time. This information can be used to analyze, for example, if a public space is visited by visitors or by local people. Moreover, it may be useful for profiling: for the users visiting a certain place or service user Spatio-temporal footprints can be defined to identify people who mainly move locally, regionally, or internationally, and where they come from.

The opportunities for the use of SMGI in spatial planning, arising from the first pilots results and the development of the SMGI analytical framework, guided the design of an original user-friendly suite of tools, called Spatext (SPAtial-TEmporal-tEXtual Toolbox), which eases the extraction and management of information from multiple social media platforms and the contextual integration in GIS environment for analysis. The Spatext suite is implemented as Python 2.7 add-in for the commercial software ESRI ArcGIS©, including a number of tools, which may be used i) to retrieve social media data from several social networks and platforms, namely Twitter, YouTube, Wikimapia, Instagram, Foursquare and Panoramio; ii) to geocode or georeference data; iii) to conduct integrated spatial, temporal and textual analyses. The number of analytical methods available in the tool is rapidly increasing in order to include also several spatial-temporal clustering algorithms for easing the user profiling, user movement analysis, user behavioral analysis and land use detection from SMGI. The Spatext suite relies on available social media APIs to perform queries directly by the GIS interface, enabling the collection of multimedia

information regarding different topics, time periods and geographic areas. This way, the extraction, management and geocoding functionalities may directly turn social media contents into workable SMGI datasets on the fly, allowing the direct integration with other spatial data, as well as the analysis in GIS environment with off-the-shelf instruments to support analysis, design and decision-making in urban and regional planning processes.

The tools included in the Spatext suite are designed and implemented to deal with the issues regarding the access, management and analysis of SMGI, which presents inherent Big Data nature for the sheer volume of data, high velocity of production and consumption and the peculiar structures of data (Vieweg et al., 2010). Therefore, the provided tools may be classified in three different categories, according to the specific design function: i) data collection, ii) data management and iii) data analysis. The first category includes a set of tool that enables SMGI extraction from several social networks through spatial, temporal or textual queries. These tools facilitate the direct access to social networks APIs avoiding programming efforts to the final user. The second category tools are developed to ease the integration of SMGI extracted from the different sources into GIS environment. The tools are designed to convert different SMGI data models into workable GIS formats. Finally, the third category contains tools designed for analyzing the dimensions of SMGI, namely spatial, temporal and user, as well as, the embedded textual contents. The architecture of the Spatext suite is shown in Figure 3, while a brief description of available tools is provided in Table 1.

Figure 3. The Spatext suite architecture

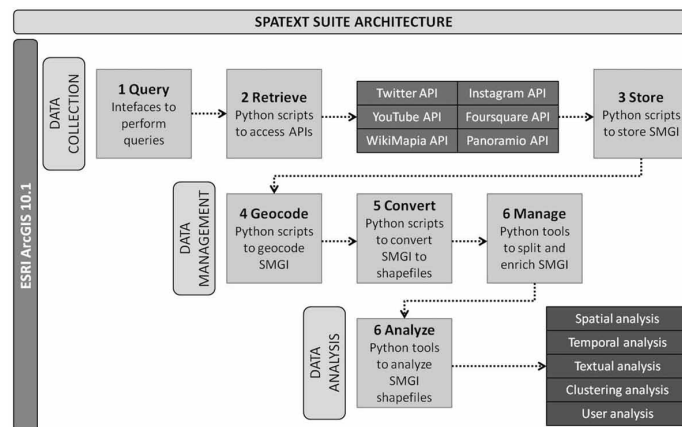


Table 1. Set of available tools in the Spatext Suite

SPATEXT SUITE TOOLS				
CATEGORY 'DATA COLLECTION'				
		Query Parameters		
Tool Name	Function	Space	Time	Keyword
Instagram extractor	Extracts Instagram SMGI to shapefile	✓	✓	✓
YouTube extractor	Extracts YouTube SMGI to shapefile	✓	✓	✓
Instagram Places extractor	Extracts Instagram Places SMGI to shapefile	✓		

continued on next page

Table 1. Continued

SPATEXT SUITE TOOLS				
CATEGORY ‘DATA COLLECTION’				
Twitter extractor	Extracts Twitter SMGI to shapefile	✓	✓	✓
WikiMapia extractor	Extracts Wikimapia SMGI to shapefile	✓		✓
Foursquare extractor	Extracts Foursquare SMGI to shapefile	✓		
Panoramio extractor	Extracts Panoramio SMGI to shapefile	✓		
CATEGORY ‘DATA MANAGEMENT’				
		Function Activation		
Tool Name	Function	Manual	Automatic	
Geocode address	Geocoding place/address from string	✓		
Geocode table	Batch-Geocoding place/address from table		✓	
Georeferencing	Georeferencing SMGI coordinates		✓	
Decomposition tools	Decompose SMGI shapefile in multiple shapefiles	✓	✓	
Google™ Static Maps	Add Google Static Map URL in SMGI attribute fields	✓		
CATEGORY ‘DATA ANALYSIS’				
SPATIAL AND CLUSTERING ANALYSIS				
Tool Name		Function		
DBScan (Density-Based Scan)		Run DBScan algorithm (Ester et al., 1996) on SMGI feature class to detect density clusters and add the cluster group in a new field of SMGI feature class		
Feature-Based DBScan		Run DDBscan algorithm (Ester et al., 1996) on SMGI feature class to detect density clusters for each group in SMGI feature class (e.g. User)		
Advanced SQL maximum		SQL selection on a SMGI feature class to detect maximum values for a specific group (e.g. User Cluster exposing max number of points)		
TEXTUAL ANALYSIS				
Tool Name		Function		
Attribute to string		Creation of a text file from an attribute field in a SMGI feature class for textual analysis		
Attribute to table		Creation of a table from an attribute field in a SMGI feature class for textual analysis		
Attribute to tag-cloud		Tag-clouding analysis from an attribute field in a SMGI feature class		
Selection to tag-cloud		Tag-clouding analysis from a spatial/attribute selection in a SMGI feature class		
Text to tag-cloud		Tag-clouding analysis from a text file		
TEMPORAL ANALYSIS				
Tool Name		Function		
Identify Month/Weekday/Day/hour		Add the Month/Weekday/Day/hour of creation in a new field of SMGI feature class		
Trend Day/hour		Creation of a 24h/60min time graph and statistic report from SMGI feature class		

SMGI Analytics Framework in Practice: The Case Studies

The growing SMGI production and availability over the web is leading to innovative analysis scenarios in spatial planning and Geodesign, which may contribute to increase smart city performances. The integration of SMGI with A-GI may offer potentially boundless and affordable knowledge concerning not only geographic facts but also local communities' perceptions and opinions in space and time. Nevertheless, a shared analytical framework to collect, manage and process this information for different purposes is needed to fully exploit this potential. In addition, in order to deal with the aforementioned privacy issues, particular attention was paid to data anonymization in the proposed case studies, and furthermore, SMGI was processed to identify macro phenomena and local communities' dynamics, avoiding issues for identifying individual users' behaviors and preferences.

In this section, the findings of several research studies, are presented, which explore and formalize a novel approach to SMGI analytics, based upon the Spatial, Temporal, and Textual analysis of SMGI. The first case study deals with the use of SMGI as a complementary information source to official authoritative information for tourism planning at the regional and urban levels. The study investigates the relationships between tourists' satisfaction, geographic location and tourism industry supply. Then, several case studies developed at the local scale and strictly related to urban planning, are presented. The urban context is analyzed by integrating A-GI with SMGI collected from the YouTube, Instagram and Foursquare. The objective of these case studies is twofold: testing the previous assumptions and demonstrating the capabilities and opportunities of SMGI as complementary source of information to A-GI in order to investigate urban dynamics and local communities' opinions for analysis and decision-making in spatial planning.

Analyzing Tourists' Demand through SMGI

The first case study concerned the qualitative and quantitative investigation of the relationships between tourists' satisfaction, geographic locations and Tourist Lodging Services (TLS), with the aim of supporting tourism planning strategies at the regional and the urban levels. The analysis workflow started with the data collection for the whole Sardinia region (Italy) from two of the most popular tourism-related social networks (i.e. Booking.com and TripAdvisor.com) and their integration with A-GI. Spatial and statistical analysis techniques were applied, in order to identify the most popular destinations, the relationships between the TLS quality and their locations, and the spatial distribution of tourists' preferences at the regional and local levels.

Operationally, the study is implemented through the following steps:

1. Data collection and geocoding;
2. Regional preferences dynamics analysis;
3. Local preferences dynamics analysis; and
4. Geographically weighted regression (GWR).

The first step consisted of the construction of a database that included data extracted from TripAdvisor.com and Booking.com. A database of tourists' ratings related to 1992 Tourism lodging services (TLSs) and almost 1 million of TLSs related comments, is extracted from TripAdvisor.com and Booking.com for the period May 2012-May 2013 and used for analysis. The main issue was to manage this enormous

amount of information. Thus, the study required the adoption of a mixed methodological approach, according to which quantitative information, concerning the scores of tourists' evaluation criteria, and qualitative information, including tourists' textual reviews, were collected in a database. Geocoding was executed on the extracted addresses for each TLS within Sardinian region.

After the preliminary descriptive analysis of the preferences dataset, spatial analytical techniques were applied in order to identify locations of interest and to detect spatial patterns of tourists' preferences and their relationships with different territorial variables, at the regional scale. Data were normalized and ranked on the same scale. The analysis of the tourists' positive preferences led to discovering the level of satisfaction with the destination and its services, which may provide useful clues for choosing the most sustainable tourism development options in case of other destinations. Spatial distribution of the Tourists Positive Preferences Incidence (TPPI), which identifies locations already affected by the phenomenon and areas suitable for future tourist developments, were carried out, demonstrating most of the municipalities located along the coastal area attract tourists, while the inner areas are less popular (Figure 4).

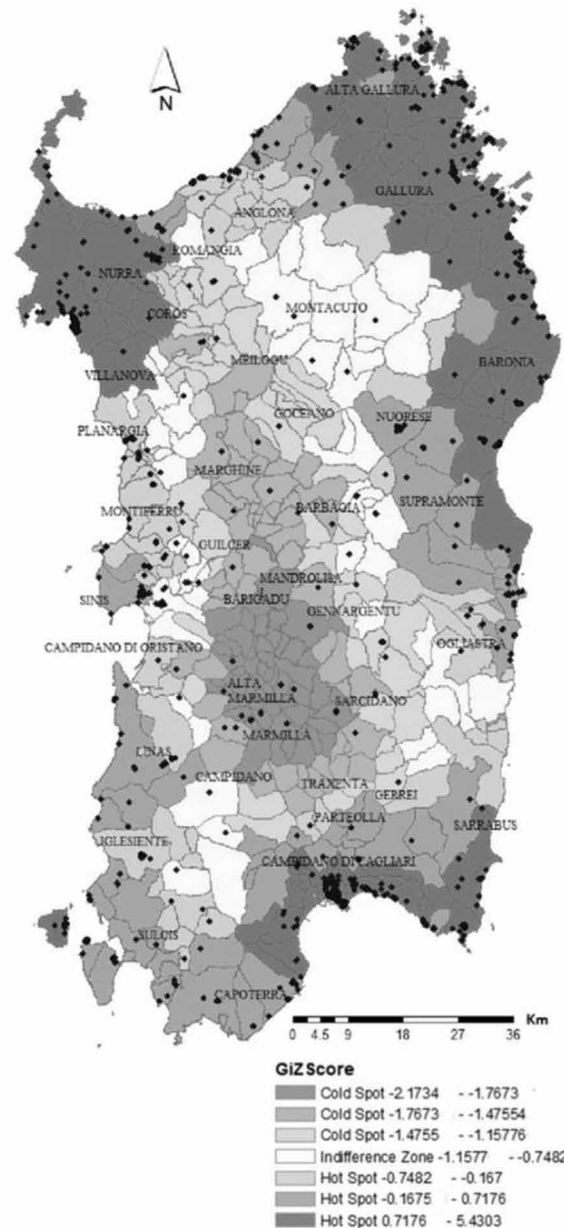
In order to understand the tourist dynamics within a single spot of interest, the urban scale was considered for more detailed analyses, relying on spatial analysis and spatial statistics techniques on an integrated SMGI/A-GI database concerning the destinations, which showed highly-successful tourist performance. The aim of this step was twofold. On the one hand, the study was performed to discover why tourists prefer some destinations rather than others (qualitative analysis); on the other hand, a quantitative assessment related to the location of tourists' preferences and to factors that contribute to high TPPI rates at the urban context, was implemented.

A case study related to the municipality of Cagliari, in the South of Sardinia, was carried out. The location of each TLS located in Cagliari allowed detecting sites where the preferences of tourists who visited the destinations were focused on; thus, it was possible to answer questions such as, What areas attract the tourists' attention? Spatial clusters of preferences were detected by hot-spot analysis. Firstly, a threshold distance of 1,700 meters is identified and then the spots by census tract summarized. Figure 5 displays the spatial distribution of values of TPPI in Cagliari; the red areas, located in the inner areas of the municipality, show a high concentration of the TPPI phenomenon (hot spot), while the blue areas represent locations where the phenomenon is less intense (cold spot).

Then, the analysis focused on the reviews content, in order to understand not only where but also what tourists think about the destinations. Hundreds of textual reviews were investigated through spatial textual temporal analysis or STTx to local subsets of data obtained by selecting high TPPI values based on the TLS locations in the case of Cagliari. The textual analysis (Table 2) clearly shows that the majority of the words in the posts refer to spatial or physical aspects, such as 'center', 'city', and 'church'. The results include keywords related both to leisure sites, such as 'restaurants' and 'shopping', and to services, such as 'staff' and 'room'. Moreover, the outcomes indicate that a high level of satisfaction is related to accessibility: words as proximity and walking could be related to the spatial location of services, natural resources or monuments. So, ease of movement from a site to another generates a positive tourist destination image. This kind of information complements existing official data on tourists' presence, enriching our understanding of success or failure factors in tourism destinations.

Finally, the analysis integrates SMGI into A-GI concerning transport infrastructure, cultural heritage sites, and socio-economic features. The spatial relationships and the explanatory factors behind observed spatial patterns were modeled using the GWR. The GWR was adopted to locate zones with homogeneous tourists' preferences (TPPI rate) within urban areas with homogeneous environmental, structural and positional variables. The model was applied to a sample of 150 TLSs spatially distributed

Figure 4. Clusters of tourists' positive preferences incidence (TPPI)



over 100 of the 1359 Cagliari's census tracts. The dependent variable is the TPPI, normalized as fraction of the comments that are favorable to a location belonging to a census tract. For each census tract, a measure of the set of independent variables was calculated. Preliminary results suggested excluding some explanatory variables from the model, because they did not comply with the Variance inflation factor (VIF) test (Mennis, 2006). The VIF test provides a measure of the size of the multicollinearity generated by the inclusion of an explanatory variable in an ordinary-least-squares regression model. It has been assumed that a variable should be excluded from the set of the explanatory variables if the VIF

Figure 5. Significant patterns in Cagliari

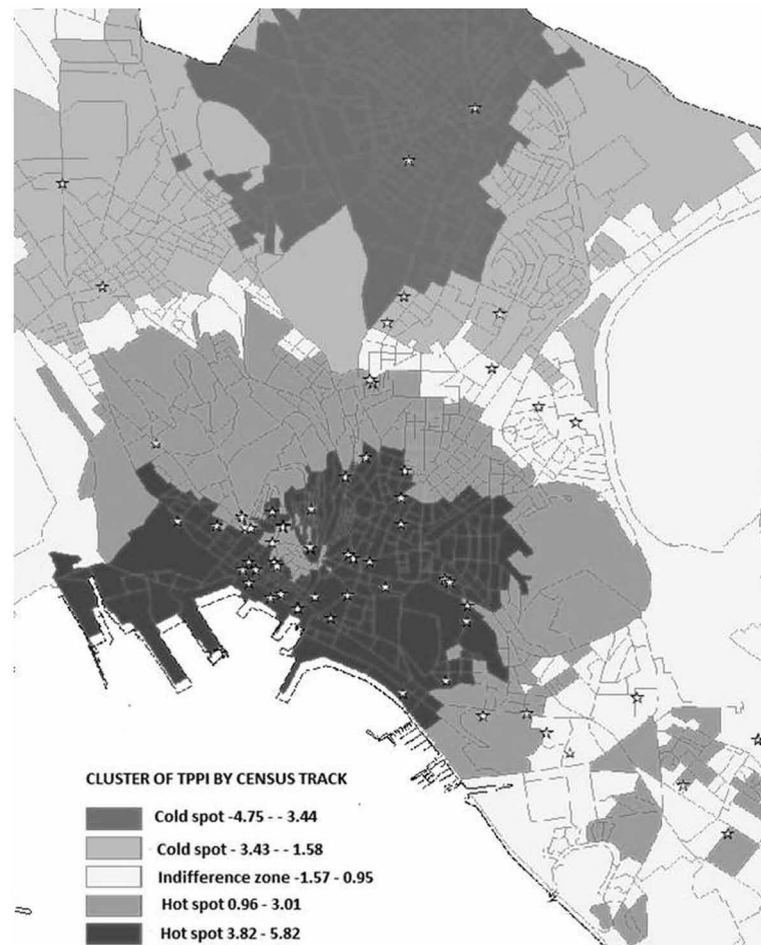


Table 2. Top 15 words related to Cagliari by category

Category	Words [Frequency]
Geographic location	location [1010]; town [476]
Service	staff [890]; restaurant [643]; room [459]; hotel [469]; pool [230]; food [180]
Accessibility	minutes [250]; harbor [237]; proximity [164]; walking [146]
Natural and not-natural components	city center [426]; beach [378]; old city [132]

is greater or equal to 10. The results of the statistical tests for measuring redundancy suggested that the following candidate variables are included, normalized by the total area of the census tract:

1. Number of historical buildings;
2. Number of restaurants and facilities;
3. Hectares of natural protected areas;
4. Distance from the airport;
5. Proximity to the historic center of the municipality; and
6. Distance from the municipality's beach.

The assumption was that if the value of the normalized TPPI is similar to the values that it takes in the closest spatial units, then the variable is characterized by spatial autocorrelation. A spatially-lagged explanatory variable was added to control for spatial autocorrelation of the dependent variable. The presence of spatial autocorrelation (Anselin, 1988) related to positive preference, whose value is the normalized TPPI, was detected through the Moran's test (Moran, 1950). The result of the local Moran's index was quite significant at the second order of queen contiguity in respect of results obtained using a threshold distance of 2,500 meters: adjusted R-squared was less than 40%, the p-value of the coefficient of the dependent variable is very significant ($1.0 \cdot 10^{-8}$) and the value of the Moran's index was 0.024. The very low p-value indicates that local spatial autocorrelation of the dependent variable was highly significant.

The results concerning the goodness of fit of the spatial regression shown in Table 3 are significant: R-squared is as high as 86%, which indicates that variables in the model explain about an 86% of the variance of the positive tourists' preferences.

The outcomes of the GWR model are quite significant for the description of the spatial distribution of TPPI. The coefficients of the variables related to the proximity to the city center, to the distance from the airport and to the proximity to the beach, which concern the TLSs' location, were almost always significant (p-values less than 5%) and show positive signs.

Table 3. Results of the spatial regression model: influence of each explanatory variable on the dependent variable

Variable	Coefficient	Std. Error	Z-Value	P-Value
TPPI_lag [19]	0.0663	0.0307	2.1621	0.0306
Constant	0.0031	0.0102	0.3012	0.7633
N_restaurants	-0.0390	0.0300	-1.3013	0.1932
Proxy_historic_center	0.4748	0.0585	8.1146	0.0000
N_hist_buildings	-0.0273	0.0313	-0.8724	0.3830
H_natural_areas	0.0027	0.0096	0.2834	0.0777
Distance_airport	0.7661	0.0340	22.5511	0.0000
Distance_beach	0.5470	0.0383	14.2922	0.0000

The variables related to the historical buildings and to the restaurants were not very significant, for the p-values are greater than 10%, while the hectares of natural protected areas show a coefficient significant at 8% and a positive sign. Overall, these findings suggest that the spatial interest of the tourists is quantitatively influenced by the models' explanatory variables. The values of the coefficients, related to the TLSs' locations show positive effects of geographic position and facilities supply on the spatial patterns of tourists' preferences.

Understanding travel behavior and tourists' expectations is very important both in determining the success of a single destination and implementing tourism planning strategies at urban level. In fact, the knowledge concerning tourists' preferences may help in assessing issues which planners need to address. In the Cagliari case study, the regression model results show that the sustainability strategies based on tourism could be effectively implemented into planning policies, whose objective is to increase the tourists' satisfaction with TLSs located in the Cagliari's municipality. Referring to the results summarized in Table 3, these policies could be identified and included into a Municipal Master Plan, for example, as follows:

1. Improving protection of the municipality of Cagliari's natural areas in qualitative terms, since the coefficient of variable 'H_natural_areas' is positive in sign and significant;
2. Improving the accessibility of the Cagliari's historic city center, and implementing urban renewal as well, based on the restoration of residential buildings for tourist reception within or close to the historic center, since the coefficient of variable 'Proxy_historic_center' is positive in sign and significant; and
3. Improving the accessibility of the Cagliari's beach and increasing the supply of facilities for tourist reception available nearby the beach, since the coefficient of variable 'Distance_beach' is positive in sign and significant.

These results can also offer a benchmark for future comparative trend analysis and directions for future tourism policies.

Using SMGI in Urban Planning: Some Examples in Deeper Analysis

In this paragraph, a number of exemplificative case studies are presented in order to demonstrate the rationale of the SMGI analytics framework application in the domain of urban planning. Two different case studies are conducted at the local scale, by taking advantage of SMGI collected from YouTube, Instagram and Foursquare. The case studies aimed to demonstrate the capabilities of SMGI as complementary source of information which considered local communities' opinions, preferences and behaviors, enabling the contextual study of urban dynamics and movements, for informing analysis and decision-making in spatial planning processes.

The first example concerns the investigation of the differences in perceptions and opinions as expressed by YouTube video publishers on several neighborhoods and an urban park area in the Municipality of Cagliari (Italy). The sample includes 385 videos extracted from January 2013 to January 2014 and partitioned as follow: 101 videos for Marina, 93 videos for Castello, 84 videos for Is Mirrionis and 104 videos for Molentargius. The 'Castello', 'Marina' and 'Is Mirrionis' neighborhoods, as well as, the 'Molentargius' Regional park were selected because of their physical, functional and social differences. The analysis was conducted by means of a tag-cloud analysis and a consequent manual semantic clas-

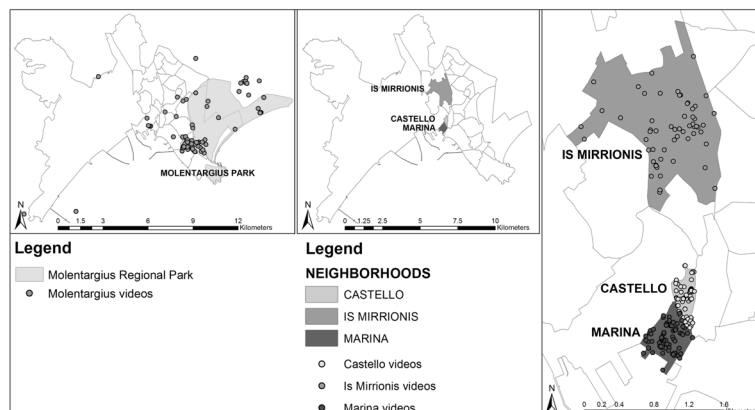
sification on textual contents of video title and caption metadata. The textual analysis allowed to identify the most significant words related to places, events and values for each neighborhood and for the park area, eliciting information that usually is not provided in official land use documents or data sources and defining a clear picture of the users' overall perception for each area. The words related to 'Castello' depicted the neighborhood as the historical one, meanwhile 'Marina' was figured as the leisure and retail one. The 'Is Mirrionis' neighborhood was identified as the location for football-related activities, and the words stressed the presence of an urban park called 'Park of Monteclaro'. Finally, the analysis of contents related to the 'Molentargius' park highlighted several features related to flora and fauna, as well as toponyms. The results of textual analysis are provided in Table 4, while the spatial distribution of video is shown in Figure 6.

The second case study concerns the analysis of Instagram SMGI related to the urban environment of the Iglesias municipality in Sardinia, Italy. Currently, Instagram may be considered one of the most popular online social networks, and recent statistics show that 20 percent of the Internet users aged 16 to 64 have a personal account on the service, which is gaining increased popularity over years (Global-WebIndex, 2014). Among the Instagram features, the geotag, allowing users to georeference the shared

Table 4. Tag-cloud analysis results: major interests and concerns related to Cagliari's neighborhoods. (Italian meaningful words are in italic)

Textual Analysis of Video Title and Caption	
Area of Extraction	Keywords (Frequency)
Castello	<i>Cagliari</i> (48), Urban (10), Safe (10), Concert (6), <i>Marmora</i> (6), Palace (5), Royal (5), Historical (4), Cathedral (2), Bastion (2)
Marina	<i>Cagliari</i> (40), Tournament (10), <i>Monteclaro</i> (7), <i>CUS</i> (6), Soccer (4), Football Club (4), Sound (4), Final (4), Music (3), Park (2)
Is Mirrionis	<i>Cagliari</i> (61), <i>Santa Lucia</i> (13), Concert (9), New Year's Day (6), Celebration (6), <i>San Sepolcro</i> (5), Music (5), Festival (4), Harbor (4), Church (4)
Molentargius Regional Natural Park	<i>Cagliari</i> (62), <i>Quartu Sant'Elena</i> (15), Salt mine (10), Flamingo (8), Park (8), <i>Poetto</i> (5), Conference (5), Service (5), Pond (4), <i>Monte Urpinu</i> (3)

Figure 6. Spatial distribution of videos related to neighborhoods in Cagliari



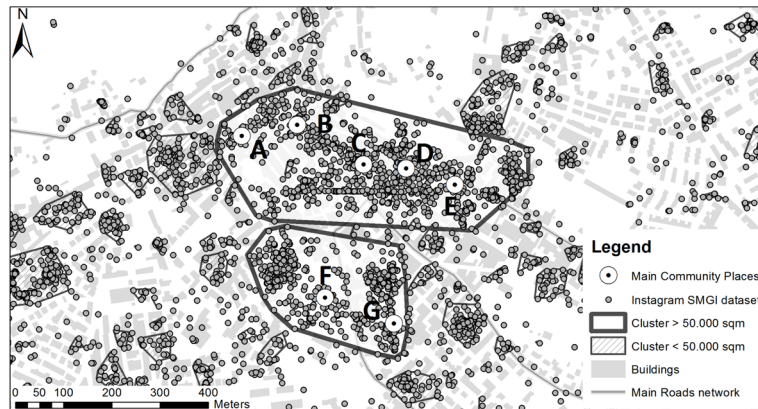
contents, might pave the way for investigating spatial and temporal patterns within any geographic area where the service is available. The case study concerning the Iglesias municipality (Italy) took advantage of the Instagram SMGI for a twofold purpose: (1) to explore the geography of the place through spatial and temporal patterns of the contributions, investigating the locations of major interest for the local community, and (2) to identify and classify SMGI clusters in order to detect potential missing buildings in official datasets.

The data extraction for the Iglesias municipality was conducted through the Spatext Instagram extractor tool and resulted in about 14K geotagged photos from 1243 users for a one year period (from 1 August 2013 to 1 August 2014). The spatial and the temporal dimensions of the SMGI dataset were analyzed in order to detect potential patterns of interest within the area and to investigate the local community' dynamics. The spatial distribution investigation showed a high concentration of the placemarks in the urban environment, while the analysis of temporal trends allowed the identification of two peaks of interest for both workdays (Monday to Friday) and weekends (Saturday to Sunday). The peaks were identified during the periods 14:00-15:00 and 21:00-22:00 for workdays, and 14:00-15:00 and 20:00-21:00 for weekends, probably suggesting a major use of Instagram during meals or pause times.

Afterwards, the results of exploratory investigations led towards the development of further analyses to study the geography and the urban dynamics of the municipality. Particularly, the high density of SMGI in the urban environment guided the development of analytical methods to identify and classify the users' interest toward specific locations in the municipality. For this purpose, the Density-Based Spatial Clustering of Applications with Noise, namely DB-SCAN (Ester et al. 1996), was used to compute clusters relying exclusively on the spatial distribution of SMGI. The cluster analysis identified 290 clusters in the urban area of Iglesias, exposing a major concentration near the city center. Furthermore, two clusters with an area greater than 50.000 square meters emerged from the analysis, pointing out the areas which attract the major interest of the users. In order to explain the major attractiveness of these areas, the Spatext Foursquare extractor tool was used to collect SMGI concerning locals and points of interests (POIs) within the two main clusters from the Foursquare' platform. The investigation of the Foursquare SMGI dataset showed how these areas concern both the historical center of Iglesias and a number of service and public areas. The top cluster contains (A) the historic Cathedral of 'Santa Chiara', (B) the historic 'La Marmora' square, (C) the main avenue for leisure and night life, namely 'Via Matteotti', (D) the main square 'Piazza Sella' and (E) the train station. The bottom cluster concerns (F) the public park of Iglesias and (G) medical services. The results of the analysis are shown in Figure 7. These results may be considered an important descriptor of the city physical structure, as well as, a valuable indicator of users' preferences and dynamics. The presence of historic area near the city center, coupled with a number of public spaces and services might stoke the users to frequent these areas.

Along the same vein, a cluster analysis was performed on the Instagram SMGI dataset in order to identify and classify SMGI clusters related to residential use, possibly detecting missing buildings in official datasets. In this case, a slightly modified version of the DB-SCAN algorithm, namely the Feature-Based DB-SCAN of Spatext, was used in order to detect exclusively the locations of major interest for each user. Indeed, the Feature-Based DB-SCAN runs iteratively on the dataset after performing a grouping selection on a specific attribute, in this case the user, for each cycle. This way, the tool was used to compute clusters related exclusively to a specific user for each iteration, enabling the investigation of users' behaviors and preferences. The analysis resulted in 368 clusters from 266 user, which were further investigated to detect the residential ones by integrating the latest official buildings dataset and by evaluating a set of parameters related to spatial and temporal characteristics concerning the cluster

Figure 7. Spatial clusters in the Iglesias city center



itself or the included SMGI contributions. For each cluster, the overlaps of both the cluster centroid and the contained contributions' barycenter were compared with the official buildings footprints. At the same time, the cluster density and intersections with other clusters, the number of included SMGI contributions, as well as the temporal span among contributions, were evaluated. The analysis identified 87 potential residential clusters which were visually assessed through an overlay analysis with satellite imagery in GIS environment. The visual assessment confirmed as residential the detected clusters, enabling in addition the identification of 9 not-mapped buildings in the official dataset. An example of the analysis results is provided in Figure 8, showing six different clusters (i.e. A, B, C, D, E and F), their barycenters, the official buildings footprints, and the Instagram SMGI dataset.

Figure 8. Visual assessment of residential clusters



In the proposed example, the visual assessment by means of satellite imagery allowed the detection of a not-mapped building in the cluster E. At the same time, the results confirmed the residential buildings in the clusters A and B and allowed to detect three public spaces, namely the cluster C, D and F, which are used by residents for leisure.

The proposed examples, built upon the use of YouTube, Instagram and Foursquare social networks, contribute to demonstrate how SMGI might be proficiently used to elicit information not only related to the physical geography of the places, but also to gain insights about the perceptions and opinions of places, as well as, the associated issues in space and time from the involved community's contributions. This capability may add a pluralist perspective of great relevance for spatial planning and decision-making, disclosing opportunities for the study and the investigation of innovative analytical methodologies, which may be informed by (near) real-time experiential knowledge of local-community.

VGI, SMGI and Public Participation

The presented example case studies show the potential of SMGI as complementary information for A-GI in real-time monitoring of the territorial dynamics, as well as novel source of information, which may give valuable insights about community perspectives and needs. As such, SMGI may represent an unprecedented media to support public participation in spatial government.

If we look back at the Arnstein ladder of public participation (Arnstein, 1969) and at its adaptations to e-participation (Kingston, 1998; Carver, 2001), as shown in Figure 9, it becomes easy to support this hypothesis. Especially in the case of active SMGI platforms, it might be possible to establish bidirectional flows of communication, which, according to the Carver's model (2001), may support higher levels of public participation. In the case of passive SMGI this link is less evident. Nevertheless, although passive SMGI may be not considered an active form of communication, its availability may affect the knowledge building phase, constituting the basis for design and decision-making in spatial planning and Geodesign processes.

Figure 9. Public participation ladder models

DEGREE OF CITIZEN POWER	CITIZEN CONTROL	PP IN FINAL DECISION	increasing participation ↑	ONLINE DSS	Communication ↑	bidirectional
	DELEGATED POWER	PP IN ASSESSING RISK AND RECOMMENDING SOLUTION		ONLINE OPINION SURVEY		
	PARTNERSHIP	PP IN DEFINING INTERESTS, ACTORS, AND AGENDA				
FORMAL PP	PLACATION	restricted PP			ONLINE DISCUSSION	Mono-directional
	CONSULTATION	PUBLIC RIGHT TO OBJECT				
	INFORMING	INFORMING THE PUBLIC				
NO PP	THERAPY	PUBLIC RIGHT TO KNOW	communication barriers			
	MANIPULATION		ONLINE SERVICE DELIVERY			
Arnstein, 1969		Kingston, 1998 after Weideman & Femers, 1993		Carver, 2001 after Smyth, 2001		

From a different perspective, we can also look at social networking platforms as digital city initiatives. According to a classification given by Aurigi (2001) a digital city can be implemented as a (digital) machine city, where citizens are passive users of service, designed and driven by experts or as a (digital) informative city, used to inform and create consensus on civic issues. While the former type may be considered inspired by a web 1.0 mono-directional technocratic communication paradigm, the latter is closer to the web 2.0 and social media paradigm. Nowadays, it is quite common in many developed countries to offer both an institutional website of the former type, and at the same time to maintain a presence on major social media such as Facebook or Twitter to engage in discussion with citizens. However, aspiring at a more radical paradigm of higher participation we should design a (digital) shared city, where the expert is a facilitator in a vast arena of public and private actors empowered to shape the virtual initiative (Aurigi, 2001). Social media as an enabling technology platform may also support such type of digital city.

However, with social media platforms used as a passive source of information there is a risk of the development of a social key-hole digital city, where authorities or other agencies may observe community preferences and behaviors. Whether this scenario would support public input affecting the knowledge development models or would be used to open the way to therapy or manipulation (Arnstein, 1969) so reducing the level of public participation is a major ethical issue, which is still to be fully comprehended. Nevertheless, easing the access to SMGI sources and analytics to the wider public may represent a factor for democratization of knowledge, thus balancing power relationships between public and private agencies and the broader community.

CONCLUSION

Nowadays, the availability of digital geographic information is fostering a knowledge revolution in spatial planning. On the one hand, developments in SDIs are enabling the access and reuse of Authoritative Geographic Information (A-GI); on the other hand, progress in Web 2.0 technologies and connectivity are nourishing the diffusion of Volunteered Geographic Information (VGI) and Social Media Geographic Information (SMGI). However, for their Big Data nature, VGI and SMGI, show a different model from traditional vector dataset model, paving the way for the exploration of innovative analytical methods.

The SMGI model relies on the concept of placemark as unit of information and features not only a spatial and a temporal reference for the embedded multimedia content, but also a user dimension, which offers people perceptions, insights and needs. Hence, SMGI may be useful as support to express pluralism in analysis, design and decision-making in spatial planning, nevertheless ad-hoc analytic methods are required to fully elicit the knowledge potential and to demonstrate to what extent this information can be used in planning practices. In order to address these issues, the authors presented several case studies that formalize and demonstrate a novel approach for the integration and analysis of communities' perceptions from different Social Media. This approach may help to understand people observations, feelings, or needs, and possibly affect planning processes and decision-making dynamics with customer oriented strategies. In addition, several analyses are provided to demonstrate how SMGI may be directly used and integrated with traditional A-GI in GIS environment by means of the Spatext Suite, enabling different kind of analysis on this information.

Altogether, the case studies analyses demonstrate how it is possible to introduce new dimensions of analysis in order to build useful knowledge for design and decision-making in spatial planning and governance. In the first case study tourist preferences on destinations and tourism industry services were analyzed from the spatial perspective through the review judgments collected by TripAdvisor and Booking.com. Results show which are the most popular destinations or areas and what tourists appreciate at the regional and the urban levels. In the Cagliari case study, a set of spatial analysis and statistics techniques were used in order to describe and to visualize the spatial distribution of tourist preferences and to detect patterns and single spots of tourist interest, specifically. The results provide insights on tourism dynamics, which are not available through other data sources traditionally used in spatial planning. In addition, the regression model results show that the sustainability planning strategies, based on tourism, could be effectively implemented into planning policies, whose objective is to increase the tourists' satisfaction in the studied area.

The Iglesias case study suggests that the locations, attracting the major users' interest within the Iglesias municipality, are placed in the public spaces of the city center and in the historical areas. The most appreciated places are the historic Cathedral of 'Santa Chiara', 'Via Matteotti', namely the main avenue for leisure and night life of the municipality, the squares 'Piazza La Marmora' and 'Piazza Sella', and the urban public garden. These results may be considered a trustworthy indicator of users' preferences, as well as, an important marker which describes the city physical structure and the urban dynamics. The presence of the historic area coupled with several public spaces and services nearby the city center, might stoke the popularity of these areas among user. Moreover, the results of land use investigation, carried out by clustering analysis, allowed the recognition of users' residential areas and the identification of several buildings un-mapped in official information. These findings demonstrate the profitable use of SMGI in respect of the questionnaires, which should be conducted on a local community's sample for obtaining similar results.

From an analytical perspective, the methodological approach proposed by the authors might be proficiently used in planning practices, easing to take into account the real users' requirements and preferences, as depicted by their preferences and movements, freely provided through the social networks. Such knowledge may be used at all stages of the planning process starting from the description of the current state of the territorial system – whatever the scale –, following with the investigation of system evolution dynamics, and with its evaluation informing the definition of future transformation scenarios which can be then assessed against user preferences eventually supporting decision-making.

The lesson learnt from this kind of analyses may be used in spatial governance, at the regional and at the local level, in order to identify the factors which may help in developing sustainable strategies, aiming to implement specific planning policies in less popular areas. Indeed, the adoption of an integrated framework, exploiting both technical and experiential knowledge supplied by A-GI and SMGI, respectively, may help in identifying the reasons behind users' preferences and urban dynamics. Further research is currently under development in order to explore the potential of integrating multiple SMGI data sources together. Nevertheless, the research may be considered in its early stage and the SMGI analytics framework proposed is likely to evolve substantially in the future to provide further opportunities for pluralist knowledge building and collaboration in spatial planning.

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Chapter 11

Urbanizing the Ambient: Why People Matter So Much in Smart Cities

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ABSTRACT

The purpose of this chapter is to develop and explore the ambient urbanizing concept as a way to shed light on what happens at the urban level when people become more aware and attuned to smartness and ambience in everyday city spaces. The research design for this work includes a case study approach and multiple methods of quantitative and qualitative data collection and analysis. In parallel with this study, anecdotal evidence gathered from individuals across the city through informal individual and group discussions enabled further analysis, comparison, and triangulation of data. This chapter makes a contribution to the research literature across multiple domains; sheds light on the emerging relationships of awareness in the people – technologies – cities dynamic, highlighting the critical role of people, in their everyday urban activities, interactions, and experiences; and offers a proposed ambient urbanizing framework for enriching spaces, things, and designs in smart cities.

1. INTRODUCTION

This chapter explores aware technologies and aware people in the formulation of emerging understandings of urbanizing the ambient in 21st century cities. Building upon Sassen's work on urbanizing technology in the context of smart cities and Weiser & Seely Brown's (1995) work on calm technology design, this chapter explores the ambient urbanizing concept through the constructs of awareness, attention, and attunement. Calm technology, as in, invisible or ubiquitous computing, is variously known as pervasive computing, ambient computing, to name a few, depending upon the research lab (Dourish & Bell, 2011). Using a minimally viable city-focused platform as a space with real-time, real-world, social media components, the ambient and ambient urbanizing concepts are explored. The mechanisms of noticing, idea-generation, and the sharing of content about the city contribute insight into the ambient-related constructs under study – awareness, attention, and attunement.

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The significance of this chapter is that it provides a conceptualization of ambient urbanizing in the context of 21st century smart cities with an emphasis on the combination of aware people and aware technologies. As such, the objectives of this chapter are to: a) explore emerging understandings of aware-enabled smart cities; b) shed light on what happens at the urban level when people become more aware and attuned to smartness and ambience in everyday city spaces; and c) explore urban level activities contributing to urbanizing the ambient, giving rise to the ambient urbanizing concept as emerging perspectives on the importance of people in smart cities.

The research design for this work incorporates a case study approach and multiple methods of quantitative and qualitative data collection and analysis. Use of a minimally viable city-focused platform as a space for thinking and sharing about the city is followed up with an interview about use experience of the tool and semi-structured questions about the city as smart. In parallel with this study, anecdotal evidence gathered from individuals across the city through informal individual and group discussions enabled further analysis, comparison, and triangulation of data. A more detailed discussion of the methodology for this work is described in section 4. A selective review of the ambient, urbanizing, and smart cities research literature in section 3 provides a theoretical perspective for the chapter in support of the deductive portion of qualitative data analysis, to complement emergent aspects of the inductive analysis portion.

Section 2 provides additional background and context for this chapter in terms of motivation; the ambient, urbanizing, and smart city concepts, incorporating emerging and developing perspectives and challenges from the research literature; along with definitions for key terms used in this chapter.

2. BACKGROUND AND CONTEXT

This chapter is motivated by the need for engaging people in more meaningful discussions about smart city phenomena. In response to the unprecedented challenges associated with rapid urban growth in the 21st century (Charoubi et al., 2012), Nam and Pardo (2011) articulate the smart cities concept as a way for cities to innovate themselves using information and communications technologies (ICTs). Gil-Garcia, Pardo, and Nam (2016) advance smarter as the new urban agenda while Ojo, Dzhusupova, and Curry (2016) identify current gaps in the smart cities research literature. Relevant to this chapter are the research gaps (Ojo et al, 2016) pertaining to the *dimensions* of education and of people and the *research approach* of living lab, as in real world everyday life. The smart city topic is present on the agenda of policy-makers, technology companies, and academics, yet city inhabitants do not seem to be involved in meaningful discussion about the concept and its implications for surveillance, privacy, inclusion and many other issues (Craglia & Granell, 2014). Further, the smart cities concept is said to be unfamiliar to more than 61% of the 1000 surveyed by Frost & Sullivan (Gamble, 2014). The concept has emerged as contested and controversial in the smart cities research literature (Greenfield, 2013) with utopian and dystopian visions (Townsend, 2014; Marvin, Luque-Ayala, and McFarlane, 2016, Hollands, 2016) and is articulated in terms of tensions and implications by futures researchers (IFTF, 2011). Smart cities have been evolving over the last decade (Scholl, 2016) yet Brandt (2015) notes a kind of obliviousness in the United Kingdom where “nearly 100 percent do not notice smart cities growing around them.”

Smart cities are enabled by a confluence of at least four developments: the emergence of information and communication technologies (ICTs) (Charoubi et al., 2012) including smart/ambient technologies (Weiser & Seely Brown, 1995); the openness movement, encompassing open source, open data, open

access; the emergence of citizen science and crowdsourcing (Craglia & Granell, 2014; Sasso, Konomi, Arikawa, & Fujita); and the concept of inverse infrastructure (Egyedi & Mehos, 2012), with ad hoc, user-driven, adaptive development from the bottom up, broadening the potential scope of agency and involvement (Angus, Lane, & Roussos, 2014). It is worth noting that many of the key elements and indicators of smart cities such as livability, walkability, sustainability, resilience to name a few (UN, 2015; Cohen, 2014) can be found in the city planning literature and new urbanism works pre-dating the smart cities movement (Jacobs, 1961; Gehl, 1968, 1980; Whyte, 1988; De Certeau, 1984).

William, Robles, and Dourish (2009) argue for an emphasis on urban experience and users embedded as actors in the global networks of interactions and flows. To this end, Williams et al. (2009) explore ‘urbane-ing’ in terms of the concept of city in the context of urban informatics. Seely Brown (2014) refers to a forthcoming work co-authored with Pendleton-Julian (Design unbound) that will bring forward the complex challenges, as in ‘wicked problems’, facing education (Johnson et al., 2016) and characterizing 21st century cities (Charoubi et al., 2012) and the need for “skillfully reading the currents and disruptions of the context around us.” Where Sassen (2013) articulates the need for an urbanizing of technology, this chapter focuses more specifically on the urbanizing of ambient technologies with an emphasis on the importance of people in a people-technologies-cities dynamic.

Further context for this chapter is provided in the key terms and definitions section, with definitions for key terms used. A selective review of the smart cities and ambient research literature provides a theoretical perspective for the chapter, focusing on the constructs of awareness, attention, and attunement. The research design for the study upon which this chapter is based is described in the methodology section, followed by an overview of findings and a discussion of the analysis and results. The implications for practice and research that this chapter makes are identified followed by study challenges and mitigations and the conclusion.

3. THEORETICAL PERSPECTIVE

This section presents a selective review of the research literature for smart cities in terms of issues, controversies, and problems as they relate to the theme of urbanizing technologies and more particularly, ambient technologies, in 21st century cities. The literature on ambience and the ambient will be presented along with the related constructs of attunement, awareness, and attention to shed light on the relationships between aware people and aware technologies. The city literature is reviewed at the intersection of urbanism and smart cities, touching on theories around people; urban environment interactions; perceptions and experiences of everyday life; urban planning; and placemaking. A discussion of the urbanizing of technology (Sassen, 2012) follows and more specifically, urbanizing the ambient.

3.1 Ambience and the Ambient

Rickert (2013) claims that “we are entering an age of ambience” where “boundaries between subject and object, human and nonhuman, and information and matter dissolve” pushed further, in part, by ubiquitous technology, affecting our interactions and what we know “about self and the world.” More than two decades ago, Weiser (1994) described ubiquitous computing as working toward the highest ideal of making computing invisible where it becomes “so imbedded, so fitting, so natural, that we use it without even thinking about it.” Weiser referred to work on the “building of versions of the infrastructure-to-

come” at Xerox PARC “in the form of inch-, foot-, and yard-sized computers we call Tabs, Pads, and Boards.” Much of this infrastructure in the form of smartphones, sensors, outdoor jumbotron displays we now take for granted.

Rickert (2013) suggests that, “ambience allows us new perspectives” and is “an ensemble of variables, forces, and elements that shape things in ways difficult to quantify or specify” since, the elements are “simultaneously present and withdrawn, active and reactive, and complexly interactive among themselves as much as with human beings.” Rickert (2013) describes ambience as “less driven by connection and more resonant with immersion and permeation” and like a network “connotes distribution, coadaptation, and emergence.” In the context of urban form, Lynch (1989), in defining settlement form, refers to ambiances, and later describes this as “the set of encompassing conditions” in the city, as in, “light, noise, microclimate, smell” (Lynch, 1996). It is worth noting that Smith (2015) identified “four emerging sources of authority” in relation to health and well-being as, “computation, narratives, networks, and ambience” adding that these sources “will fundamentally transform who we trust and what interventions will be available.”

Rickert (2013) argues that “ambience is itself ambient” and McCullough (2013) suggests that, “when you feel renewed sensibility to your surroundings you might try calling this ambient.” In articulating how to arrive at an understanding of ambient, McCullough itemized 12 possible ways, three of which are highlighted here for their relevance to this chapter. First, McCullough describes ambient as, “that which surrounds but does not distract”; second, “a continuum of awareness and an awareness of continuum”; and third, “rampant availability of opportunities to shift attention.” The first description brings to mind Weiser’s (1994) notion of computing as imbedded, fitting, and natural, suggestive of attunement. The second description of ambient makes a connection and association with awareness and persistence. The third description is noteworthy because it makes a connection with attention. The ambient will now be discussed in terms of the three associated constructs of attunement, awareness, and attention.

3.1.1 Attunement

Rickert (2013) claims that “ambience involves more than just the whole person” and “is inseparable from the person in the environment that gives rise to ambience” and as such, involves the notion of attunement. Rickert (2013) describes attunement as “not additive” but “a fundamental entanglement,” arguing that, “what is public is as ambient as it is salient.” For Rickert, “ambience guides, calls, or suggests according to our ability to attune to our emergence in the situation.” Weiser and Seely Brown (1995) suggested that it is how technologies “engage our attention” that gives rise to whether they will be encalming, as in, ambient. And as such, calm or ambient technology “engages both the center and the periphery of our attention,” moving “back and forth between the two” where periphery refers to, “what we are attuned to without attending to explicitly.” Weiser and Seely Brown (1995) argue that “by placing things in the periphery we are able to attune to many more things” and “by recentering something formerly in the periphery we take control of it” enabling awareness and control from the periphery.

3.1.2 Awareness

Discussing awareness in human-computer interaction and computer-supported collaborative work (CSCW) environments, Dourish and Bellotti (1992) claim that, “awareness information is always required to coordinate group activities, whatever the task domain.” Dourish and Bellotti point to “an awareness of

the activity of others” as providing “a context for your own activity” and through information sharing in a mode encompassing synchronous, asynchronous, and semi-synchronous, the “workspace becomes a persistent space in which collaborators can interact” in support of active or passive awareness. Dourish and Bellotti (1992) argue that, “awareness information provided and exploited passively through the shared workspace, allows users to move smoothly between close and loose collaboration and to assign and coordinate work collaboratively.”

Weiser and Seely Brown’s (1995) notion of calm technology, as in ambient, is described in terms of the three characteristics of “motion between center and periphery, peripheral reach, and locatedness.” Windows within an office space are used as a design example “that enhances peripheral reach and locatedness.” The inner office window is for Weiser and Seely Brown (1995) “a metaphor for what is most exciting about the Internet” and by extension, social media spaces, in terms of “the ability to locate and be located by people passing by on the information highway.” Internet multicast video is used by Weiser and Seely Brown (1995) as an example of a “window of awareness” with continuous, two-way interaction enhancing presence and responsiveness with added attunement opportunities.

Erickson and Kellogg (2000) focus on visibility, awareness, and accountability in the development of socially translucent systems to support graceful “communication and collaboration among large groups of people over computer networks.” Jacobs (1961) noted the importance of visibility on a city and community level. Where Jacobs speaks in terms of just enough control to decide what and to whom to reveal details about self, Erickson and Kellogg point to the importance of constraints enabling adjustments, where socially translucent is proposed rather than socially transparent in response to the “tension between privacy and visibility,” thus the need for awareness and accountability. As such, Erickson and Kellogg point to the importance of technologies with windows rather than walls that, “mesh with human behavior” at “individual and collective levels.” This type of translucence allows “users to ‘see’ one another, to make inferences about the activities of others, to imitate one another” in order for “new social forms” to be “invented, adopted, adapted, and propagated.”

Dourish (2004) noted that in CSCW “visibility is generally addressed as the support for awareness in collaborative systems” and that “awareness is the informal, often tacit, understanding that collaborators have of each other’s activities.” Dourish (2004) adds that awareness technologies “provided group members with views or representations of each other and their work, to help them coordinate their actions smoothly.” Bellotti & Sellen (1993) provide a design framework to address privacy issues in ubiquitous systems from a technical rather than a social or policy solution perspective, serving also to “elucidate the delicate balance that exists between awareness and privacy.”

Through studies with audio-video communication Dourish, Adler, Bellotti, & Henderson (1996) argue that “the media-space world *is* the real world” and as such, “it is a place where real people, in real working relationships, engage in real interactions.” Baude (2015) lends further support to the real world nature of online environments by claiming that the Internet is an innovation of space.

McCullough’s (2013) description of ambient as “a continuum of awareness and an awareness of continuum” possibly gives ways to Seely Brown’s (2014) description of designing a technology “that lets us look through the screen instead of at the screen” leveraging the “synergistic relationship between the center and the periphery” in order to “look through the information and on to the world” and the larger context.

3.1.3 Attention

Contributing to the notion of the attention economy, Simon (1971) articulated the scarcity of attention in relation to information, stating that “in an information-rich world, the wealth of information means a dearth of something else: a scarcity of whatever it is that information consumes.” For Simon, information “consumes the attention of its recipients” and as such, “a wealth of information creates a poverty of attention.” However, Weiser and Seely Brown (1995) point to the paradox of how what appears to be information overload can be overcome in that “the way to become attuned to more information is to attend to it less.” As such, peripheral awareness supports “an increased sense of locatedness” making way for social interactions and human empowerment (Weiser & Brown, 1995).

Bellotti, Back, Edwards, Grinter, Henderson, & Lopes (2002) address interaction issues in ‘sensing’ systems from a human-human design perspective by focusing on communication. Posing five questions, Bellotti et al. (2002) present design challenges related to smart/sensing systems, one of which focuses on attention. McCullough (2013) notes that Seely Brown (2014) “emphasized the attentional principle of ‘periphery’” and for both Weiser and Seely Brown (1995) “periphery was everything you were aware of that didn’t consume your attention, and that could be brought to the center of focus if necessary.” McCullough (2013) notes the importance of “attention to surrounding” and that it is a “fundamental theme in urbanism.” Lynch (1960), describing the moving elements of the city, referring in particular to people and their activities, points to the importance of *legibility*, as in, the clarity, safety, and ease with which the city can be navigated. Lynch describes the physical form of cities in terms of five elements – paths, edges, districts, nodes, and landmarks, noting that this contributes to heightening attention and enriching experience.

3.2 Urbanizing Technology and the Transitioning from Cities to Smart Cities

The works of many can be seen to form the essence of the people dimension of smart cities assisting in the transitioning from cities to smart cities.

3.2.1 Cities and Everyday Life

Jacobs (1961), concerned with “how cities work in real life” addressed the ordinary and everyday “to promote social and economic vitality.” Also concerned with everyday life, De Certeau (1984), discussing spatial practices in “walking in the city”, describes the city as “a place of transformations and appropriations” that is “the object of various kinds of interference but also a subject that is constantly enriched by new attributes.” It is instructive to note that discussion of urban form by Lynch (1989) in terms of *settlement form* or the physical environment is described as “the spatial arrangement of persons doing things.” Lynch adds to this, “the resulting spatial flows of persons, goods, and information and the physical features which modify space in some way significant to those actions, including enclosures, surfaces, channels, ambiances, and objects.” Whyte (1988) spent hours walking around New York City during the 1970s and 80s rediscovering public spaces and the city at the street level and observing their use by people. Whyte credits the proselytizing work of architect Gehl (1968) with contributing dramatically to the pedestrianizing of the city center in many cities around the world.

3.2.2 Smart Cities and Urbanizing Technology

In 2008, Hollands explored the ‘real smart city’ in terms of, “intelligent, progressive or entrepreneurial” and more recently (2016) points to the diversity of ideas, debates, and understandings pertaining to the smart cities concept. Hollands (2016) questions what he sees as the trend of cities increasingly “becoming a backdrop to corporate advertising and the privatisation of public spaces.” Hollands points to Harvey’s (1989) notion of a shift in city governance from managerial welfare to urban entrepreneurialism where cities capitalize on the smart city movement. In terms of alternatives, Hollands, drawing on the work of Hill (Ampatzidou, 2013) and de Waal (2013), points to the importance of “people and citizens” and to “social learning and social cooperation.” Hollands (2016) provides alternative examples of community projects involving people and social media, highlighting the “right to use the technology” and the “right to shape the city using human initiative and technology for social purposes,” As such, the notion of ‘urbanizing’ comes into play as well as the concern with the people and learning dimensions of smart cities (Nam & Pardo, 2011).

Sassen (2012) articulates the urbanizing concept in relation to technology and the need for smart city technologies to be able to “work within a particular urban context.” An example of urbanizing a new addition to the city, albeit extreme, was enacted and later documented by Petit (2002) through a high-wire walk between the Twin Towers in New York City. Controversial from conception, when the Twin Tower structures were finally completed, owners had difficulty attracting people to the new space. However, Philippe Petit was fascinated with the structures from the early stages of their development. After considerable planning and preparation, Petit emerged early one morning to perform aerial artistry in a high-wire walk between the two structures, at the 1,350-foot level for 45 minutes. Thousands of people on their way to work took notice of the spectacle, with the Mayor of the city among the viewers. Arrested for this illegal and arresting act of creativity, Petit was later released and instead, was assigned community duty to perform for the children in Central Park. Among the outcomes from this event that captured the attention and imagination of people in the city was the effect of humanizing the structures, as in, urbanizing and warming people to this new space encompassing many types of technology including that of verticality.

Issues associated with smart cities and the urbanizing of cities, include, but are not limited to, privacy, surveillance, visibility, and translucence.

3.2.2.1 *Privacy and Surveillance*

Greenfield (2013) is critical of smart city initiatives and solutions that place an emphasis on technology over people, contributing a space of controversy to the smart cities movement. Townsend (2014) presents utopian and dystopian perspectives on smart cities, identifying three key issues of concern – the buggy-ness of software driven systems; the brittleness of systems that may not be highly adaptive, responsive, or resilient; and being bugged by a surveillance society. As if in anticipation of Townsend’s third concern, Mann (2013) proposes the perspective of sousveillance enacted by people in cities with the increasing presence of mobile/wearable cameras/recording devices such as smartphones. Jacobs (1961) noted that, “people’s love of watching activity and other people is constantly evident in cities everywhere.” Jacobs goes on to point out the critical role of ‘watching’ in the city and the importance of densification and diversity to support social and economic vitality in the city. Jacobs makes the connection between city surveillance and city safety where city design supports people to keep an eye on spaces in their neighbor-

hoods as part of intense daily activities and use. Jacobs notes that “privacy is precious in cities” and that sharing much of nothing does not work but being in control of what is shared and of how much, matters.

Addressing issues of brittleness, Sassen (2012) argues for the urbanizing of technology if smart cities are to be successful and overcome the challenge of closed systems obsolescence. As a solution, Sassen proposes that open source be extended and applied not just to technologies but also to cities, as in, open source urbanism. Townsend (2014) details a range of open source efforts in terms of the open-source metropolis. For Sassen, open source urbanism accommodates the software of people’s practices. Sassen questions whether the very complexity of urban spaces when combined with the software of people’s practices may leverage what is needed to overcome the buggyness and brittleness of smart cities. The incompleteness of cities is emphasized by Sassen (2012) and it may be that as the urban is continually in-the-making, this buggyness can be understood as a space and opportunity for creativity, intervention, and collaboration in making cities smarter.

Combining the terms urban and capability, Sassen (2013) seeks to “capture an elusive mix of space, people, and particular activities” as constituting urban capability. For Sassen, this social and material physics of the city gives way to a kind of speech, enabling the city to talk back. Supporting the argument for urbanizing technologies is the concern identified by Sassen with three forces contributing to deurbanization – inequality, privatizing urban spaces, and surveillance systems. It may be that Mann’s notion of sousveillance as undersight (2013) is a way of urbanizing technologies of watching in the city. Mann & Ferenbok (2013) point to the use of wearable and mobile technologies as enabling “unprecedented ‘on the ground’ watching of everyday life” to provide undersight and the potential for balancing the oversight of surveillance systems in the city.

3.2.2.2 Visibility and Translucence

Gehl (2010) notes the importance of translucence, as in, “being able to see through windows” as an enhancer for people in the city, both from the inside and outside of buildings. This is reminiscent of Weiser & Seely Brown’s window metaphor for technologies that enable visibility and a seeing through to the information and the world, and of the translucence work of Erickson and Kellogg (2000).

Gehl is concerned with the livability of cities and with “human quality in the public realm” from a humanistic planning perspective, calling for “lively, safe, sustainable, and healthy” cities (2010) and highlighting concern for the human dimension. For Gehl, designing cities for people must take into consideration two fundamentals – human mobility and human senses as the “basis for activities, behavior and communication in city spaces.” Whyte (1988) placed an emphasis on people, in designing urban environments, informing contemporary urban initiatives around placemaking in the context of Project for Public Spaces.

Gehl claims “there is much more to walking than walking” noting that “it is also – and most particularly about – the city as meeting place,” As such, enabling “direct contact between people and the surrounding community” and “experiences and information,” walking is fundamentally “a special form of communion between people who share public space as a platform and framework.” Gehl makes reference to activities associated with walking in the city in terms of their versatility and complexity, “with much overlapping and frequent shifts” in the type of walking along with unpredictability and unplanned, spontaneous actions.” Oldenburg (1999) makes the case for the importance of informal public life and meeting places. Oldenburg’s (2001) third place or space as “a setting beyond home and work in which people relax in good company” is needed “to construct the infrastructures of human relationships.” Me-

marovic, Fels, Anciето, Calderon, Gobbo, & Carroll (2014) provide a rethinking and extending of third places in the context of ICTs with implications for visibility and presence awareness.

Sassen (2012) challenges the development of smart cities such as Masdar City in Abu Dhabi, United Arab Emirates as costly and difficult to replicate examples, functioning as a kind of lived-in laboratory. The concept of arcology advanced by Solari (Solari et al., 2012) is a combining of architecture and ecology and Masdar City is said to be inspired by arcology principles (Dellesky, 2014). Mone (2015) claims that new smart cities are beginning to emerge, drawing on the combined efforts of “academics, civic leaders, businesses, and individual citizens working together to create urban information systems.” With sensor embedded technology, Mone (2015) refers to gadgets “talking to the city itself” yet, emphasizes the importance of people in this ecosystem and the endless possibilities of open data. Cohen (2015) identifies multiple generations of smart cities as: 1.0 where technology is driven by providers; 2.0 as city-driven, technology enabled; and 3.0 as involving citizen co-creation with the city.

3.3 Ambient Urbanizing

Ambient urbanizing is advanced in this chapter as an approach to theorizing the urban on the one hand and as a type of methodology on the other, contributing to a larger area of emerging cities methodologies (UCL, 2015). The combining of resources, skills, and disciplines opens the way for theorizing around ambient urbanizing in this chapter. As technologies become more aware and are being pervasively and ambiently used by people and cities, the potential exists for enhanced awareness.

3.3.1 Ambient Public Displays

Cuff, Hansen, & Kang (2008) pointed to the possibilities for pervasive computing enabled by cell phones as “passive sensors that can silently collect, exchange, and process information all day long.” Gehl noted the importance of active facades that encourage people to slow down or stop, noting that people were seen to interact more with their cell phones. Memarovic, Langheinrich, & Alt (2012) offer an interacting places framework (IPF) for promoting community interaction and place awareness (CIPA) using public displays that incorporate ubiquitous wireless communication and sensing. Memarovic et al. (2012) explore the challenges and opportunities of this type of open networked pervasive display, highlighting the four elements of: content providers, content viewers, interacting places communication channels, and an awareness diffusion layer. Memarovic et al. (2012) make reference to implicit awareness diffusion “through the effect of Legitimate Peripheral Participation (Lave & Wenger, 1991) where people learn about a place and its community by observing interests of others.” Synthesis of research in this area (Memarovic, 2015) contributes to an understanding of challenges going forward.

3.3.2 Ambient Sensing and Spectacle

Ambient urban visualization has been discussed in different contexts, from participatory sensing of environmental data in the city (Kuznetsov, Davis, Paulos, Gross, & Cheung, 2011) to the legal, and the privacy implications of sensing going public and “making the invisible visible” (Cuff et al., 2008). Kuznetsov et al. (2011) provide an example of urbanizing the ambient in the form of colored balloons containing sensors reflecting environmental quality by color as the balloons are moved around the city performing

as sensors in the sky. Kuznetsov et al. (2011) identify this type of visualization as spectacle computing, enabling participatory sensing, focused on air quality in the city, activating attention and awareness.

Focusing on everyday practices, Stengers (2010) points to their dynamic and performative nature where people “adapt, improvise, and experiment.” Weiser (1994) highlighted Jeremijenko’s ‘dangling string’ display as a new direction in invisible or ubiquitous computing, providing an early example visualizing ethernet packets physically and in an ambient way.

Lynch (1996) noted that artificial light “now offers largely unexploited resources of color, form, and sequential change” adding that “prevailing microclimates, by small areas, and the intensity, character, and rhythm of city sound affect all observers.” Artificial light is also an important consideration in relation to urban display screens from large jumbotron to small handheld devices. Microclimates will also be important in terms of spaces enabled by ambient screen displays.

As theorized in this chapter, ambient urbanizing calls for increased thinking and discussion about awareness and aware technologies in the creation of smarter cities. Utilizing a people-technologies-cities interactive dynamic, this work contends that increasing awareness and understanding about aware-enabled technologies is critical since such technologies are intricately interwoven into and throughout everyday life (IFTF, 2015). As such, aware people when combined with aware-enabled technologies, is theorized to contribute to the enhancing of human potential and the enriching of urban experiences and spaces.

In this chapter, the ambient urbanizing concept is operationalized using the activities of noticing in the city and the sharing of ideas for the city as proxies for the constructs of awareness, ambience, and smartness. What people do with an early-stage urban-focused social media space like AboutTheCity-i2 is designed to contribute to discussions, understandings, and potentials for ambient urbanizing. This exploration of ambient urbanizing gives rise to three research questions identified in section 3.4.

3.4 Research Questions

- **Q1:** Why is urbanizing the ambient important in 21st century cities?
- **Q2:** How does urbanizing the ambient occur in contemporary cities?
- **Q3:** What approaches to urbanizing the ambient serve to enrich urban experiences and spaces?

4. METHODOLOGY

The research design for this work includes an exploratory case study approach and multiple methods of quantitative and qualitative data collection and analysis. Webpage use, interview, and open-ended survey form the basis for qualitative data collection, analyzed using content analysis. Survey (closed-ended) and use experience activity data constitute the quantitative collection portion.

This study spans a 7-month timeframe from mid 2015 into 2016, across multiple cities (Langford, Ottawa, Toronto, Victoria, and Jyväskylä) of small to medium to large sized populations, mostly in Canada but also extending to Finland in northern Europe. Interest and involvement was sought from individuals 18 years of age or older. In parallel with this study and beginning 5 months earlier, anecdotal evidence was gathered over a 1-year period through informal individual and group discussions with people across the city. The study methodology is described in terms of the process, sources of evidence, and the data analysis.

4.1 Process

People across six sectors of the city were invited to participate in the study (e.g., city officials, local business, educators, community members, students, and visitors to the city) and given a link to the city-focused web platform for AboutTheCity-i2. People who registered to participate in the study were then given access to three spaces: a Noticing page for contributing content; an Ideas page for contributing content; and TheCity page where contributed content is dynamically displayed. Participants were then invited to talk about smartness in their city in an interview. In this study, i-2 refers to iteration 2, featuring a mobile platform with direct accessibility, by-passing the need to download or install an application. Figure 1 presents the user interface for the AboutTheCity-i2 platform in two screenshots.

The screenshot on the left in Figure 1 provides a space for participants to contribute information about noticing in the city in the form of text, links that may connect to other sites and multi-media, and tags. Similarly, a space is available for generating and contributing ideas about the city. Contributed content is immediately viewable, with one click, by other participants as shown in the screenshot on the right in Figure 1. At a glance, participant responses pertaining to noticing and ideas are viewable and browsable, along with the date of the contribution; the city name; the anonymized ID of the contributor (e.g., AtC00); why what is noticed matters; what the idea is about; and a description of the idea.

In concept, this platform, when used with a mobile smartphone for example, is intended to foster noticing, thinking, and discussion about the city. In design, this platform is minimalist, intentionally under-designed, and is intended to foster and enable attention to, awareness of, and attunement with the city through sharing moments of noticing and idea generation about the city. As a user interface this platform is limited in capability, enabling the capture and display of data through the use of embedded Google forms. Regarding use, this space offers a combining of content and context as a quick, easy-to-use, in-the-moment tool to possibly engage, give pause for thought, and inspire.

Respondents were also given the option to complete an online survey about their use experience with AboutTheCity-i2 and about smartness in their city.

Figure 1. AboutTheCity-i2: User interface screenshots



4.2 Sources of Evidence

Sources of evidence for this chapter consist of data collected through activity tracking of the About-TheCity-i2 webspace including artifacts generated in the form of content, links, and tags contributed by respondents. Data were collected through in-depth interviews with participants using a semi-structured interview protocol. An online survey instrument with open and closed-ended questions provided an additional source of quantitative and qualitative data.

Data were collected from informal discussions with individuals and groups across the city constituting anecdotal evidence. Sharp (2014) argues for the necessity of accessing “the diversity and ambiguity of human experience” in order to “learn what matters.”

4.3 Data Analysis

Data analysis consisted of content analysis for qualitative data relying on a combination of techniques for the development of terms that on the one hand, emerge from the data (inductive) and on the other hand are advanced by the research literature (deductive). Coding terms contribute to the generation of a coding glossary in support of the coding process. Overall, data were analyzed for an $n=16$ spanning all age ranges from 20s to 70s including 45% female and 55% male.

5. FINDINGS

Key findings presented in this section are organized around the three research questions, enabling insight into what is occurring at the urban level when people become more aware, attentive, and attuned to smartness and ambience in everyday urban spaces.

5.1 Importance of Urbanizing the Ambient in 21st Century Cities

In exploring the importance of urbanizing the ambient in 21st century cities, a highly active community member in Toronto, admitted to being caught off guard by the “smart cities thing,” commenting that the “predictive aspect of technology has got me on edge a little bit.” While smart technologies were described as “extraordinarily convenient”, concern with trust was expressed and the “ethical implications of letting technology make decisions for us.” The individual added, “that conversation I don’t think has been had thoroughly yet and I can’t wait until it is”, while also expressing shock at “how quickly this concept of self driving cars has come about and this issue of drones.”

Individuals from business, the local community, and postsecondary institutions in Greater Victoria tended to associate the smart cities concept with technology, while smartness and aware technologies were associated with the notion of the automaton, as in, robotics. A community member observed that aware technologies provide affordances, “helping us to understand our communities differently, not better, but differently.”

The smartness term contributes to concerns with the need for balance associated with technologies and how important it is to “rely upon our senses” as in, “our innate sense of the way in which we engage with aspects of the city.” For example, it was suggested that awareness pertains to “everyday signs and signals” such as obvious signs of the usage of paths and not just “the current day smart signs.” As such,

awareness was seen as important for keeping in touch with “a part of ourselves” and “a part of that connection that makes the dynamic city come alive.”

Assessment of AboutTheCity-i2 and its potential for urbanizing aware spaces emerged as neutral. However, AboutTheCity-i2 was assessed as having possibilities for attuning to urban spaces and for heightening urban sensibilities.

5.2 Occurrences of Ambient Urbanizing in 21st Century Cities

Ambient urbanizing emerged as occurring in contemporary cities in a range of ways through a variety of mechanisms. Referring to city data displays tracking bike path usage, one educator commented that, relying solely on the quantification of activities in the city with numbers tends to scare people. Instead, it was suggested that new awarenesses associated with “seeing differently” be leveraged so as to educate and “to begin to enrich or enhance or permit our communities to evolve in ways they need to.” A business person commented on the additional potential of the urban data display in terms of “how can we improve” and “where are you from?” commenting that, “I think it would be interesting to have that interactivity.” A community leader described the use of infrared cameras by the city business association, capturing street data that “records the blobs” as people move around specific parts of the city.

A community member highlighted the placing of large jumbotron screens outside of sports events in Toronto, as a city experiment, extending the event inside that drew 20,000 people to include an additional 10,000 people outside.

Looking for “an opportunity maybe for making the city a little smarter” an engineering student described how “I hope to change people’s minds so they follow a more green way.” In developing a course project, the student commented that, “it would be nice if the city itself could be more interactive” and “not only the profit making companies.”

Mobility was discussed in terms of multi-modal and multi-directional uses of transport and infrastructure in a large city like Toronto by a community member who commented that “you’re not moving one way, you are walking, I’ll ride my bike somewhere, I’ll jump on a streetcar, the subway.” The PATH series of passages and tunnels underneath the city of Toronto was described as an almost game-like design so that “the city is allowing you to play in it.” A Placemaker described a library box for the free exchange of books and how the idea served to engage in diverse and unexpected ways, involving people, urban spaces, technologies (e.g., GPS, Google maps, timelapse video, social media), things in the form of books, and unexpected connection and sharing.

Using online technologies for a City Hall meeting was beneficial in the view of a Victoria City Councilor in being able to “definitely create discussion and connections” and “extend conversations on issues and ideas.” Described as a back channel by an educator, the idea of including a Twitter feed behind a conference speaker where you may have 500 people in attendance is being enriched by up to any number of additional people online.

In the context of placemaking and pop up events, a community leader commented that, “we like to do those to demonstrate how a space can change” using the example of a temporary Sunday afternoon street closure to traffic to create a pedestrian space.

A postsecondary educator pointed to “urban spaces embedded within suburban communities” as “gathering and sharing places” accommodating “unhurried and quiet” interactions. Using the example of an elaborate fountain that the city could “orchestrate with color and sound” the educator described the experience of noticing “the sounds of the fountain as I walk to catch the bus” and provided a webpage

link with an image. The fountain was highlighted because this “provides a touchstone for people in the area” as a point of interaction.

Table 1 provides an overview of public spaces amenable to the making of smarter cities through ambient urbanizing initiatives across multiple cities and urban voices.

Another factor enabling ambient urbanizing, in the words of a postsecondary educator, is “recognizing that we can turn anything into anything, so what do you want?”

5.3 Approaches to Ambient Urbanizing: Enriching Urban Experiences & Spaces

Approaches to fostering discussion and thinking about ambient urbanizing are identified in Table 2, along with emergent observations about each. People were encouraged to focus on five elements that potentially serve to enrich urban experiences and spaces, as in: what they notice about the city and why this matters; ideas they have for the city; how they feel the pulse of the city, what contributes to the vibrancy of the city, and how they sense the city.

Regarding noticing, for one community member it is the architecture, for another it is the people and their faces and whether they are friendly or happy or welcoming, and for others it is the state of the city itself in terms of “how clean it is.” For one educator it is the urban events (e.g., markets) and for another it is the example of a fountain with sound and color that becomes an enriching space, a focal point where people take notice, stop, look at each other, talk, interact, and slow down.

In terms of ideas, infrastructure was a key focus with one community leader pointing to social financing for community centers in new communities. One educator opts not to share ideas because of ownership

Table 1. Summary of public spaces for making cities smarter through ambient urbanizing

	Business	Community	Educators	Gov't	Students	Visitors
Data displays	✓	✓	✓	✓	✓	✓
Entertainment screens	✓	✓	✓	✓	✓	✓
Green urban apps	✓	✓	✓	✓	✓	✓
Mobility/Things/Tech	✓	✓	✓	✓	✓	✓
Online/Conf/Twitter	✓	✓	✓	✓	✓	✓
Pedestrian events	✓	✓	✓	✓	✓	✓
Third places (fountain)	✓	✓	✓	✓	✓	✓

Table 2. Summary of approaches to ambient urbanizing in smart cities

	Emergent Observations
Noticing	Architecture, Events (markets), Objects/spaces (fountain, screens), People, State of things
Ideas	Infrastructure, Social financing for community centres, Mobile cloud app
Pulse	Buildings, Mobility/movement, Night life, People, Students, Businesses
Sensing	Connectivity, Lost, Relaxed, Safe, Scared, Senses
Vibrancy	Connections, Dynamic, Mixed use, Multi-purpose, People

concerns and another advances a “mobile cloud app to capture and share insights for instant awareness” adaptable for “business, design, health, infrastructure, learning, safety, sport, tourism.”

The pulse of the city “is the face of the buildings” and “the actual street that you are walking on” stated one community member who added that “you can see the life.” For an educator, the pulse of the city is found in “the way people walk and talk and engage each other” and in – “the coffee shops, the businesses – the people and daily goings on.” A city councilor added that “people interacting with each other and with their surroundings, I think that’s when you get the pulse” and “when people actually say hi to each other because its creating activity.”

Sensing in the city is described by one educator in terms of enabling a getting in touch with a range of senses through, “a second of connectivity” as in, “it causes people to go, did you hear that.” A Victoria community Placemaker referred to the example of the Bastion Square Parkade Stairwell sensors project (Chamberlain, 2015) by a local technology company, in partnership with the city, other technology companies, local business, artists, and community events. Designed by Monkey C Interactive, this public artwork is described as being “about people interacting with each other” to “compose and create.” A local city councilor (Chamberlain, 2015), commented that such artworks are “designed to ensure civic parkades are safe and welcoming.”

An for vibrancy, an educator commented that, “I’ve always found an urban setting is dynamic, the energy is just electric.” A city councilor observed that, “vibrancy is created by people and connections between people and the way that comes to life – whether through arts and culture, sitting and having a coffee discussing the city and things you are passionate about.” Noting the traditional separation between work and play in the city, one participant suggested that “successful cities are everything” as in, multi-purpose spaces. As such, cities are enriched by the creation of mixed-use spaces and “it’s the people” that contribute to the vibrancy and enrichment of the city.

6. DISCUSSION

Discussion about smartness, aware technologies, and smart cities revealed a willingness to engage with the topic and to share ideas and information. However, a desire to learn and be more involved and part of the conversation, debate, and movement emerged. While awareness of smart city initiatives emerged, the extent and depth was found to be limited, along with mechanisms for becoming more actively involved.

Public spaces identified and summarized in Table 1 for making cities smarter through ambient urbanizing reveal a meshing and interweaving of people, technologies, and urban spaces. The value of noticing in the city was recognized as assisting people to become more aware and to see how things change, evolve, and grow. Contributing insight into why people matter so much in smart cities, emergent observations in Table 2 reveal that people figure into all approaches used in this study for exploring ambient urbanizing. For example, through discussions on noticing in the city, sharing ideas for the city, feeling the pulse of the city, sensing the city, and the vibrancy of the city, a circling around and interweaving of the awareness, attention, and attunement constructs emerged.

Responses are city specific and focused on the individual or group’s local city. However, it is worth noting that without exception, urban discussions and thinking about smart cities and aware technologies extended to experiences in other larger cities (e.g., Barcelona, Detroit, Helsinki, London (UK), Los Angeles, Montreal, Moscow, New York, Oulu, Paris, Portland (OR), San Francisco, Seattle, Sydney,

Thailand, Vancouver, and Vietnam). This finding contributes further to contemporary urban theorizing regarding where the urban begins and ends (Brenner & Schmid, 2015).

6.1 Role and Potential of Ambient Urbanizing

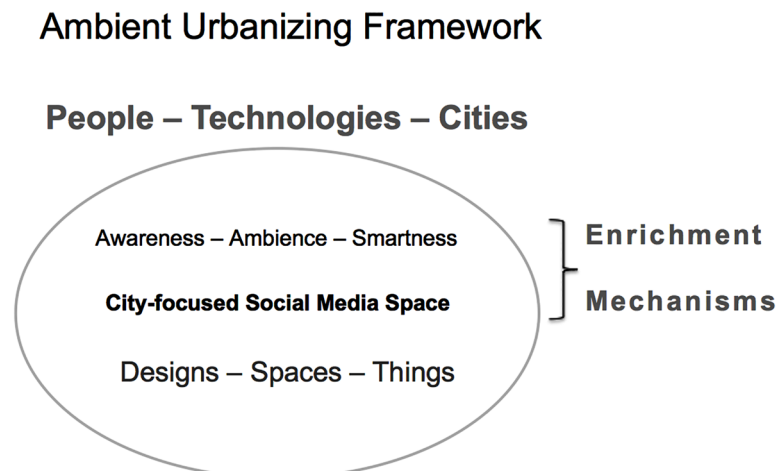
Urbanizing the ambient emerges in this chapter as important in 21st century cities for at least three reasons, in that: greater awareness is generated about aware technologies; greater awareness is developed about the smart city concept; and an urban discourse including spaces for action are generated and generative. Findings in this study enable the formulation of a proposed conceptual ambient urbanizing framework for enriching spaces, things, and designs in smart cities, as illustrated in Figure 2.

Through the interactive dynamic of people – technologies – cities, a city-focused social media space is used to explore awareness – ambiance – smartness. The ambient urbanizing framework is intended to activate awareness through noticing and sharing in the city as enrichment mechanisms for fostering smarter designs, spaces, and things. As such, this proposed framework is intended to mitigate, provide alternative perspectives, and possibly obviate concerns raised by Greenfield (2013) and others (Townsend, 2014) regarding utopian and dystopian perspectives on smart cities.

6.2 Summary

As theorized and then explored in this chapter, the combining of aware people with aware-enabled technologies opens spaces and possibilities for ambient urbanizing and the potential for contributing to the enhancing of human potential and the enriching of urban experiences and spaces. Through learning about and coming to understand ambient urbanizing, the words of Weiser & Seely Brown (1995) on learning to design calm technologies, as in ambient, echo forth, “we will enrich our opportunities for being with other people” making way for ambient technologies “to play a central role in a more humanly empowered twenty-first century.”

Figure 2. Ambient urbanizing framework for enriching spaces, things, and designs in smart cities



7. IMPLICATIONS FOR PRACTICE AND RESEARCH

Based on study findings, this chapter makes recommendations for ambient urbanizing going forward, in terms of both practice and research.

7.1 Practical Recommendations

- **Ambient Urbanizing Hackathons:** Building on local initiatives (Chamberlain, 2015), creatively explore the potential and enriching nature of ambient urbanizing.
- **Exploration, Testing, Learning, & Demonstrations:** Leverage social media and other aware technologies as city-focused noticing and awareness spaces (e.g., AboutTheCity-i2, CitizenLab, Jaxber, PlaceSpeak) in real world urban environments to engage in ambient urbanizing, generating opportunities for all while identifying emerging trends.

7.2 Research Recommendations

- **Ambient Urbanizing Framework:** The proposed ambient urbanizing framework is intended for smart city developers, planners, community members, and researchers alike. The framework will benefit from further use, testing and development, with the potential to open future research and practice opportunities in a number of domains including smart cities, urban design, ambient computing, awareness research, and the Internet of Things (IoT).
- **Ambient Urbanizing Research:** This work suggests that while the use of aware-enabled, as in, ambient technologies is well advanced, the extent and sufficiency of ambient urbanizing may be lagging, opening an area for further research.
- **Theory Development:** Insights emerging in this chapter about ambient urbanizing provide opportunities for further research and theory development.

8. CHALLENGES AND MITIGATIONS

Discussing abstract concepts such as ambient, smartness, aware technologies, and urbanizing provided challenges for many which were mitigated by interactive discussion about their cities and the presence and enriching potential of interacting with technology in public spaces. Challenges of this exploratory study pertaining to small sample size and the number, size, and geographic locations of cities are mitigated by the in-depth interviews yielding rich data along with the potential to extend this research to other locations, cities of greater scale (e.g., megacities), and urban contexts.

9. CONCLUSION

This chapter assists in coming to understand the ambient and ambient urbanizing concepts; the potential of ambient urbanizing as an enrichment mechanism for designs, spaces, and things in the context of smart cities; and why people matter in the people – cities – technologies dynamic. An ambient urbanizing framework is advanced as a way of engaging people in meaningful discussions about the smart cities phenomena. Increased awareness of the city is generated through involvement in city-focused social media spaces and other aware technologies for noticing and sharing about the city while contributing insight into enrichment mechanisms for designs, spaces, and things in urban environments.

This chapter makes several contributions, including: a) conceptualization of ambient urbanizing for the 21st century; b) further development of the research and practice literature for smart cities, awareness, and the ambient; and c) creation of a discourse space for fostering enrichment mechanisms for ambient urbanizing of designs, spaces, and things in smart cities. The key take away from this chapter pertains to how development and use of ambient urbanizing provides a way of articulating why people matter so much to the enrichment of urban designs, spaces, and things in technology-rich, 21st century smart cities. It is expected that this chapter will be of interest to a wide range of city-focused practitioners and researchers and anyone concerned with liveable, resilient, sustainable, and humanly empowered cities.

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KEY TERMS AND DEFINITIONS

Ambient: The increasing presence of aware-technologies in and around human activity affecting the nature and experience of information, attention, attunement, and awareness.

Ambient Urbanizing: Ambient urbanizing refers to how people adapt and leverage aware technologies to enhance and enrich interactions, awareness, experiences, and communications in the city.

Attention: Attention in an ambient context refers to a more fluid, porous, dynamic space involving peripheries where focus can shift awareness of something in the periphery to the foreground as needed.

Awareness: The concept or quality of being aware as it applies to people on the one hand and to technologies on the other. Noticing, for example, can be used by people as a way of becoming more aware of their environments, of others, and themselves. Social media technologies such as Facebook display presence-awareness by showing which of your friends are currently active in the space.

Engagement: Engagement refers to informed involvement in an activity, enabling meaningful and thoughtful contribution(s).

Practice: Practice refers to the methods and approaches used to accomplish a particular activity. In an ambient urbanizing context, the potential exists for ad hoc, emergent, and adaptive solutions, possibly contributing to ambient practices.

Smart Cities: Smart cities are urban areas characterized by aware people who are engaged, in combination with and aided by the use of, awareness enhancing technologies. For example, using a smartphone with location-awareness to quickly and effectively navigate in the city while using the device to share with others your noticing, discovery, or reimagining of urban spaces.

Smartness: Smartness pertains to the awareness of people, of technologies, and of people interacting with technologies in urban spaces as noted in the smart cities definition.

Chapter 12

Making Citizens' Activities Flourish through a Crowdsourcing-Based Social Infrastructure

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ABSTRACT

We now typically live in modern cities, where ubiquitous computing technologies such as advanced sensing enhance various aspects of our everyday lives. For example, smart phones offer necessary information to make our everyday lives convenient anytime, anywhere in the city; energy management and traffic management have become smarter, making our everyday lives more convenient and efficient. However, from a citizen perspective, the well-being of citizens needs to be more essential than merely achieving efficient and convenient smart city infrastructures. We think that this issue is particularly crucial for establishing the next generation of smart city design. In this chapter, we propose a social infrastructure named flourished crowdsourcing to make our society flourish, so diverse citizens will live comfortably and happily. To achieve a flourishing society, one of the most essential issues is making diverse citizens activists who will participate in socially collective activities. Traditional approaches such as gamification typically make it possible to guide the social activities of the average number of citizens, but it is not easy to maintain activities for diverse citizens. By incorporating fictionality into the real space, our approach is to increase the social awareness of citizens to achieve a flourishing society within each citizen's community so that they see the necessity of their contribution. To design and analyze fictionality, we also propose a gameful digital rhetoric as design abstractions. The design abstractions are extremely different from traditional approaches; designers can explicitly focus on the enhancement of the meaning in the real space from multiple perspectives; thus designers can change the meaning incrementally according to rapidly changing social situations or citizens' diverse preferences.

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INTRODUCTION

When designing future advanced smart cities, maintaining a desirable lifestyle from the citizen perspective is a promising research topic. There have been numerous previous studies that have focused on efficient physical resource management such as energy and traffic management in underlying smart city infrastructures. However, in a future aging society, the well-being of citizens will become more crucial than building resource-efficient smart city infrastructures; this is an essential design approach in next-generation smart city design. To overcome the abovementioned issues, altering citizen's attitudes and behaviors is crucial because adopting traditional ubiquitous computing technologies that focus on resource efficiency cannot by itself overcome the serious social problems of the present (Institute of Government, 2010; Stimmel, 2015; Wolfe, Malone, Heerwagen & Dion, 2014). Recently, some researchers have started to investigate how technologies and design strategies can make people flourish (Desmet, Pohlmeier, 2014; Quercia, Schifanella, Aiello, 2014).

Our research goal is to establish a design guideline to enhance our lifestyle towards a more desirable level in urban cities, where many citizens live, to enable them to realize human well-being. Seligman defines well-being theory (Seligman, 2011) as a theme of positive psychology. In his book, he identifies five factors needed for humans to flourish in the PERMA model, including *positive emotion, engagement, relationships, meaning, and achievement*. The factor of human well-being steers people towards desirable behavior. For example, a husband and wife who have positive images of one another can create a fruitful married life. Additionally, positive emotions reduce the risk of catching a cold or an infectious disease. Seligman claims that people without positivity tend to think that there is no way for them to improve their everyday lives whereas people with high positivity can act to have meaningful and productive lives (Layous & Lyubomirsky, 2014; Seligman 2011). Therefore, developing a next-generation smart city infrastructure should take into account how such an infrastructure helps people achieve human well-being to guide their desirable human behavior.

In our current society, we have many serious social problems that we need to overcome. To overcome some of these problems, a top-down approach may not work well. In typical cases, governments or certain ambitious individuals may tackle the problems, but most of the remaining people merely stand as spectators to their activities to overcome the problems. Then, finally, no one has any interest in performing the activities needed to overcome the problems. Now, our world has become increasingly complex, and the top-down approach does not investigate a variety of complex social issues because one issue is unconsciously connected to other issues and observing these effects in advance is not easy. Therefore, each citizen needs to cope with these issues locally. For example, to achieve sustainable environments or realize a healthy social lifestyle, the participation of diverse citizens in the activities to achieve these goals is essential. We call a society in which diverse citizens voluntarily attempt to overcome these problems a *flourished society*. In the flourished society, citizens need to increase their self-awareness regarding how they should contribute to achieving the flourished society, and they need to establish intrinsic motivation to participate in the activities to make our society flourish. However, most citizens do not understand what they need to do to achieve a flourished society. A future social information infrastructure to guide citizens' collective human behavior will help them understand and suggest what they need to achieve a flourished society. Some recent work proposed in the positive psychology research community (Layous & Lyubomirsky, 2014; Seligman 2011) offers important scientific evidence to develop a social information infrastructure to guide diverse citizens' collective behaviors towards achieving a flourished society.

Recently, digital marketing and social media practitioners have adopted a game-based approach under the term *gamification* (Deterding, Dixon, Khaled & Nacke, 2011; Huotari & Hamari, 2016) to connect people to products and services. The idea is to use game mechanics, such as those of digital games, to make a work task engaging, thus encouraging them to unconsciously complete more work tasks. Additionally, some researchers focus on changing the human behavior of individuals through persuasive technologies (Spagnolli, Chittaro & Gamberini, 2016). Persuasive technologies attempt to change undesirable human behavior through information technologies. For example, as shown in Consolvo et al. (2008) and Nakajima and Lehdonvirta (2013), presenting proper computationally changing expressions based on people's current situations or efforts may change their behavior towards a desirable lifestyle. However, the existing approaches do not address true human well-being in terms of Seligman's definitions, particularly from the perspective of collective human behavior.

This chapter proposes a social infrastructure designated flourished crowdsourcing to achieve a flourished society. As shown in the next section, digital games offer useful foundations to make our society flourish. However, the current approaches to extracting the games' key idea to guide human behavior typically focus on only individual behavioral changes. To achieving a flourished society, flourished crowdsourcing offers several strategies to guide collective human behavior to increase people's awareness of the necessity of their behavioral changes and to increase their intrinsic motivation to make them activists who achieve a flourished society. Increasing an individual citizen's awareness to achieve a flourished society is the most essential factor in making our society truly flourish (Layous & Lyubomirsky, 2014). The approach requires different strategies from traditional human motivational mechanisms such as gamification and persuasive technologies to increase the social influence among the members of each citizen's community. To increase the strategies' essential power, flourished crowdsourcing incorporates fictionality into its crowdsourcing activities. Fictionality increases the power by exaggerating the effects in the real space or by using non-existing artifacts in the real space, making it possible to increase an individual citizen's awareness of how his/her contributions to achieving a flourished society are essential. We introduce gameful digital rhetoric, which allows us to enhance the meaning of the real space to design fictionality and makes flourished crowdsourcing a social information infrastructure to guide collective human behavior through incorporated fictionality in the real space to achieve a flourished society. The chapter also presents how to help design and analyze flourished crowdsourcing to incorporate fictionality in crowdsourcing activities to engage citizens through the research method known as design fiction (Lindley, 2015; Tanenbaum, 2014).

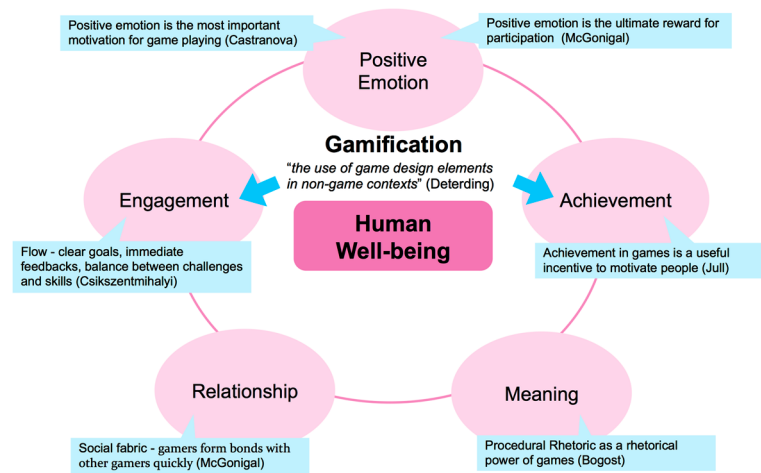
In the next section, we first present how digital games offer the possibility to make our society flourish. However, current gamification and persuasive technologies do not offer sufficient power because these approaches do not offer a strong stimulus to make diverse citizens aware of the necessity of achieving a flourished society. We next propose a social information infrastructure designated flourished crowdsourcing. Flourished crowdsourcing structures our society into many micro-communities to increase the social influence within the micro-communities. However, the social influence generated from the structuring is not sufficiently powerful to guide the collective human behavior of diverse citizens. We also propose to incorporate fictionality into crowdsourcing activities to enhance the social influence and to make diverse citizens aware of the importance of participating in the crowdsourcing activities. To design fictionality, we introduce gameful digital rhetoric, that is, a design abstraction to design and analyze fictionality by enhancing the meaning of the real space to guide collective human behavior. Finally, we describe some design implications of our current approach.

USING DIGITAL GAME CONCEPTS FOR FLOURISHING SOCIAL COLLECTIVE ACTIVITIES

A digital game, which is produced by the assembly of information technology, has the power to provide all of the factors presented by Seligman that are required to realize human well-being (Seligman, 2011). He argues that engagement is a concept related to flow. During flow, people typically experience deep enjoyment, creativity, and complete involvement with life, with the engagement that causes people to experience a flow state being an essential component in digital game design. Csikszentmihalyi notes that the flow experience has all of the building blocks of personal fulfillment, such as clear goals each step of the way, immediate feedback on one's actions, and balance between challenges and skills (Csikszentmihalyi, 1997). McGonigal states that positive emotions are the ultimate reward for participation (McGonigal, 2011). Castranova also identifies positive emotions as the single most important motivation for game playing (Castranova, 2007). Almost all digital games include immediate feedback under players' control, and well-designed digital games provide clear goals and appropriate challenges based on each player's skill. Regarding meaning, digital games have various rhetorical aspects, many of which have been discussed in previous studies; currently, rhetorical power is being reinvestigated to understand the powerful effects of digital games (Bogost, 2008). Additionally, digital games can create positive relationships, with digital games explicitly providing meaningful and valuable benefits with regard to participating in collective human behavior. In fictional game worlds, players frequently tend to mutually collaborate to achieve a shared goal because they reap individual benefits by doing so. In Massively Multiplayer Online Role-Playing Games (MMORPGs) such as World of Warcraft (Blizzard Entertainment, 2016), multiple players must cooperate to perform complex missions. McGonigal also argues that gamers quickly form bonds with other gamers. In her study, McGonigal illustrates the relationship created through collective activities in the social fabric of games (McGonigal, 2011). Moreover, achievement is often used in digital games as a useful incentive to motivate people. Digital games clarify the process of achievement by using points, badges, leaderboards and other similar features (Deterding, Dixon, Khaled & Nacke, 2011).

The foregoing discussion clearly shows that the power of digital games can enhance the five factors defined by Seligman, enabling them to become the permanent building blocks for a life of profound fulfillment oriented towards making a society flourish. As shown in the previous section, gamification is a promising approach to increasing human motivation, and it has been adopted in various digital services, in particular, various recent social media such as Facebook and Twitter. However, traditional gamification mainly focuses on only two factors: engagement and the achievement of Seligman's five factors, as shown in Figure 1. Therefore, it is difficult to achieve human well-being in terms of Seligman's definition. The two factors, engagement and achievement, are designed based on goal setting (Deterding, Dixon, Khaled & Nacke, 2011), but other factors must take into account meaning in our everyday lives. For example, as shown in Morschheuser, Hamari and Koivisto (2016) and Liu, Alexandrova and Nakajima (2011), most current approaches to enhancing crowdsourcing with gamification do not make their participants aware of the necessity of their crowdsourcing activities to maintain their long-term activities. Therefore, it is not easy to actually motivate diverse people. In particular, recent trends in the use of gamification in social media and social games mainly aim to unconsciously engage people based on behavioral psychology and not to increase curiosity or intrinsic motivation by increasing people's joy. However, the insights that we have extracted from research on digital games (Sakamoto & Nakajima, 2014a; Sakamoto & Nakajima, 2014b; Sakamoto & Nakajima, 2015a) show that digital games offer

Figure 1. Well-being and the power of games



Seligman's five factors through fictionality, not the game mechanics. Digital games strongly influence us based on their fictional worlds, which consist of computationally changing representations, through player interaction. Our approach attempts to guide human behavior through fictionality, in particular, by incorporating fictionality into the real space.

Digital games typically exploit the use of fictionality to make players aware of the meaning of the world of games. For example, the use of empathetic characters increases the familiarity with the game world where the characters appeared. We believe that the real space where we live enhances meaning by incorporating fictionality and that the real space enhances our well-being through fictionality designed based on digital game concepts. Incorporating fictionality into the real space makes it possible for a citizen to achieve a desirable situation by playing a role in a fictional story because the story makes us believe in the necessity of achieving a desirable situation, making it possible to increase our inclination to become activists (Sakamoto & Nakajima, 2015a). Because a typical fictional story describes brave heroes, dignified heroines and mysterious magicians whose strong self-efficacy allows them to overcome difficult challenges, when we play these roles in the real space, our attitudes and behavior are altered, and our own self-efficacy increases. Playing a fictional role in the real space without losing one's grasp on reality, role-playing is effective in incorporating fictionality into the real space. This style of role-playing is known as pervasive role-playing (Montola, 2007). A person's fictional experience becomes tangible when he or she feels that the embodied fictionality is realistic. Realism is the most essential criterion for the success of pervasive role-playing (Ishizawa, Takahashi, Irie, Sakamoto & Nakajima, 2015). The crucial aspect of role-playing is to increase a player's autonomy through the game's property of agency (Montola, 2007). As shown in Deci (1980), this autonomy is essential for building a player's intrinsic motivation. Therefore, incorporating fictionality becomes an effective tool in helping help citizens understand the embedded ideological messages in the story and induce their participation by increasing their intrinsic motivation, clearly reflecting Seligman's factor of meaning.

A digital game offers a virtual world that contains various virtual objects, social and economic mechanics and challenges that influence a player's behavior in the fictional world. Typical virtual objects include virtual currency, virtual humans, virtual goods and virtual clothes. Well-designed digital games offer players many attractive imaginary and artificial benefits through meaningful and valuable experi-

ences. When designing an attractive and successful digital game, a game developer defines meaning based on how a player perceives virtual objects and events in the virtual world. If a player feels that the world is meaningful, then he or she will enjoy the game. This discussion indicates that fictionality offers Seligman's positive emotion. Similarly, in digital games such as MMOPRGs, social influence is also well designed among players to guide their participation in the games. Thus, fictionality also offers Seligman's relationships. We believe that the same reasoning applies to the real space. Making citizens' lives in smart cities meaningful is crucial to influencing human behavior to make a society flourish (Sakamoto & Nakajima, 2015a; Sakamoto, Nakajima & Akioka, 2015). If we perceive that the objects and events in our real everyday lives are meaningful and valuable by enhancing them with digital game-related concepts, then our pleasure in our everyday lives is increased. For example, empathetic stories are added to name-brand products to make them more meaningful. Current gamification and persuasive technologies do not exploit the aspects of digital games to enhance the meaning in the real space through fictionality. However, offering well-designed fictionality is a key issue in incorporating human well-being in digital games. Additionally, non-existing fictional effects are promising for enhancing the real space (Ishizawa, Takahashi, Irie, Sakamoto, Nakajima, 2015; Nakajima & Lehdonvirta, 2013; Sakamoto, Alexandrova & Nakajima, 2015). As shown in Sakamoto, Alexandrova and Nakajima (2015) and Sakamoto and Nakajima (2015c), fictionality can strongly influence human behavior to make certain lifestyles highly desirable.

Based on the discussion above, the incorporation of fictionality into the real space complements traditional gamification, in particular, for achieving human well-being. However, we still need to discuss how to design fictionality and how to incorporate fictionality in social information infrastructures. To design fictionality, our proposed design concept is based on Caillois's definition of play. He captures that playfulness is only one of two modes of play, known as *paidia*: unstructured and spontaneous activities; and he also defines *ludus* which captures gamefulness: structured activities with explicit rules (Caillois, 2001). Gameful digital rhetoric includes the two modes of play noted above to design fictionality to increase the awareness of the necessity of achieving a flourished society. Our approach is also based on insights into developing several services based on persuasive technologies (Nakajima & Lehdonvirta, 2013; Sakamoto, Nakajima & Alexandrova, 2015) in which offering computationally changing expressions reflects people's current situations. The expressions present the meaning of the current situation to increase the awareness of the drawbacks of the current situation. From these past insights, we try to redefine playfulness and gamefulness from the aspect to abstract the real space for speculating gameful digital rhetoric, where designing fictionality with gameful digital rhetoric incorporates a variety of digital games' properties to make us flourish because the properties satisfy the Seligman's five factors as described above. Our approach regards gamefulness as a frame to abstract a society where people live and playfulness as a frame to abstract people's meaning-making when they perceive our society. In flourished crowdsourcing, gameful digital rhetoric is adopted to incorporate fictionality to increase the playfulness and gamefulness in the participants' activities. As shown above, fictionality enhances meaning in the real space and motivates citizens in communities.

A SOCIAL INFORMATION INFRASTRUCTURE TO MAKE CITIZENS' ACTIVITIES FLOURISH

Technological advances alone are not sufficient to achieve the goal of a better future. Citizens must alter their attitudes and behaviors (Institute of Government, 2010; Wolfe, Malone, Heerwagen & Dion,

2014). According to Faud-Luka (2009), designing people's activism is a crucial direction for overcoming various serious social problems. It aims to alter human attitudes and behaviors through a design-oriented approach. Governments embed persuasive strategies in public policies; however, this method has limits, particularly because setting public policy requires a process that takes a very long period of time (Institute of Government, 2010).

The free resources that are shared by a number of people, such as public toilets and the natural environment, tend to be overused as a consequence of the *tragedy of the commons* (Hardin, 1968). This problem occurs because each individual derives a personal benefit from using the resource, whereas any costs are shared among all of the users; this circumstance leads to use that is inconsiderate towards others. An example of this behavior is the wasteful use of free plastic shopping bags, which are filling landfills. Citizens must experience a feeling of having contributed to achieve a flourished society to be motivated to pay the necessary cost.

The roles of crowdsourcing have recently expanded in a variety of new areas, such as citizen science, civic engagement, and political campaigns, and they will become increasingly important in a modern society (Oxford Internet Institute, 2014). In crowdsourcing, each participant performs a micro-task, that is, a tiny task to be completed with a small amount of effort in which the entire task is divided into numerous micro-tasks; each micro-task requires only a small amount of time to be completed because it attempts to achieve the sustainability of a small, common resource in a person's spare time with minimal effort. Increasing citizens' awareness of how they participate in solving serious social problems is central to achieving a sustainable smart city (Lea, Glang, Blackstock, Vogt, 2015).

In flourished crowdsourcing, to explicitly guide human collective behavior, a micro-task performed in crowdsourcing to steer people towards their desirable situation should be a central concept. Additionally, to involve more citizens, these micro-tasks should be designed by a variety of stakeholders who contribute to overcoming social problems based on participatory design (Ehn, 1993). Flourished crowdsourcing offers a basic concept known as micro-communities to effectively influence community members. The fictionality incorporated into the real space strengthens social power through the techniques pervasively installed and developed in persuasive technologies. The approach increases the possibility of increasing diverse citizens' awareness of the activities oriented towards achieving a flourished society because enhancing the meaning of the real space through fictionality influences all citizens who reside in the space. The above discussion indicates how our approach takes into account the relationship factor defined in Seligman. Because our approach is lightweight and uses a smart phone, people can participate in flourished crowdsourcing activities with little effort anytime and anywhere. In flourished crowdsourcing, we aim to provide an opportunity to everyone who wishes to contribute and participate in improving our space. Each micro-task is defined as a mission that is typically used in digital games.

There have already been several crowdsourcing works to increase participant motivation based on gamification (Morschheuser, Hamari & Koivisto, 2016; Liu, Alexandrova & Nakajima, 2011). Most prior approaches attempted to increase human motivation through points, badges and leader-boards. However, our approach enhances the meaning of the real space through fictionality. Enhancing meaning in the real space may increase people's positive emotion and positive relationships. Additionally, doing so strengthens the engagement to perform activities to make our society flourish and motivate people to achieve a flourished society. Finally, the enhancement of the real space may make people's activities more meaningful. As shown in the section, our approach offers multiple design frames for designing and analyzing fictionality and increases the possibility of making diverse citizens flourish by considering fictionality from multiple perspectives through framing the meaning in the real space.

Basic Design Strategies for Increasing Social Influences

A community-based approach overcomes the issue of guiding aggressive participation in social activities to contribute to a flourished society. The most important design strategy of the approach involves using a micro-community to guide more crowdsourcing activities by increasing the social influence among participants, as shown in Figure 2. The design strategy is to adopt an altruistic society, but altruism alone is not sufficiently strong to motivate citizens when the number of community members is high and other temptations typically obstruct their altruistic behavior (McGonigal, 2013). If each community consists of a small number of members, then the possibility of a free ride is decreased (Olson, 1965). This design is essential for crowdsourcing for collective action because the existence of a large number of free riders significantly kills the motivation of active participants. This approach is also important in increasing curiosity because community members who know each other can propose a new micro-task that may be of interest to members within the same community.

With this approach, a community member in each micro-community can propose a micro-task to maintain the flourishing of the community, and other members of the community can then complete or support other members to complete the micro-task. However, members typically do not have sufficient time to contribute to a micro-task. In particular, citizens who live in urban areas are busy and have many commitments. Therefore, they typically forget the importance of achieving a desirable situation in our society. In our everyday environments, we have numerous small, common resources that are costly to maintain if maintained by the government, nonprofit organizations or individual companies. However, maintaining these resources typically necessitates tasks that can be achieved with minimal effort in a person's spare time. In our urban lives, we typically have many opportunities to take advantage of small amounts of spare time.

Figure 3 shows an overview of activities of the participants in a flourished crowdsourcing micro-community. A member of a micro-community related to a small common resource, known as a micro-task organizer, proposes a new micro-task when he or she becomes aware that an activity must be completed

Figure 2. Structuring crowdsourcing with micro-communities

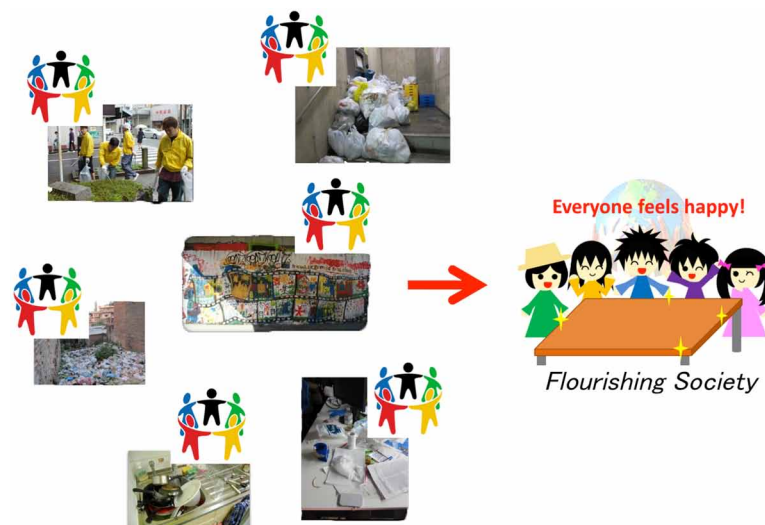
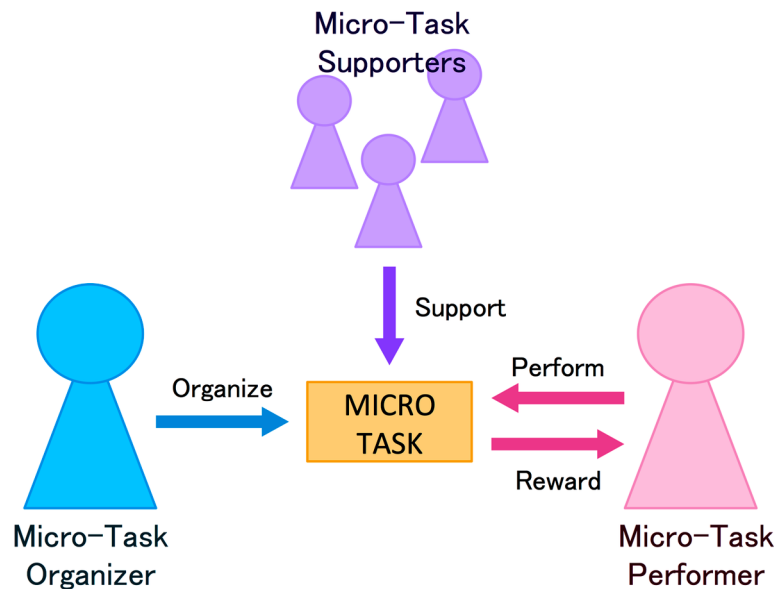


Figure 3. Overview of flourished crowdsourcing



to maintain the sustainability of the resource. Typical examples of these common resources are a public sink on a floor of a building or a public shelf used by a university laboratory. The proposal includes a summary of the micro-task, which specifies the necessary activities and the value of achieving the micro-task.

When other members, known as micro-task supporters, receive a request to support the micro-task, they decide whether they want to do so based on the delivered photograph representing the micro-task. Members who wish to support the micro-task simply click on the requests on their phones to notify the micro-task organizer. The micro-task can be performed by any member who can access the resource in his or her spare time when the total contributed value satisfies him or her. This member is known as a micro-task performer. The micro-task is typically a simple task, such as cleaning a public fountain or putting a shelf in order. After completion, the micro-task performer takes a photograph of the resource to show that the micro-task has been completed and sends it to the micro-task organizer. Finally, the micro-task organizer verifies the quality of the achievement, and notification of the completion of the micro-task is delivered to all of the members who supported the micro-task.

One typical example of flourished crowdsourcing is to increase the awareness of the necessity of our environmental sustainability. A micro-task organizer proposes a tiny mission such as picking up litter from public streets or parks or increasing the temperature setting of an air conditioner. Some participants may not be aware that these missions contribute to environmental sustainability (Shiraishi, Washio, Takayama, Lehdonvirta, Kimura, & Nakajima, 2009). In particular, micro-task supporters increase the awareness of the necessity of these missions through participations in flourished crowdsourcing activities.

This approach increases the awareness of the contributions of community members through social influence because the effects of their contributions can be easily monitored through their participation in flourished crowdsourcing activities. After the micro-task to which the community members are contributing has been completed, each community member who has supported it as a micro-task supporter receives a notification of completion as feedback. Thus, most micro-community members are ultimately aware of

the desirable situation to be achieved through the flourished crowdsourcing activities. To increase the awareness of participants, the next subsections propose several design strategies to enhance the meaning of the real space through fictionality incorporated into the real space. This approach increases the social influence within a participant's community and reflects each participant's preference and personality to make them activists who achieve a flourished society.

In typical crowdsourcing, the price of performing a micro-task is specified; however, our approach can use anything of value, not only money, and the value is enhanced through fictionality. For example, the use of virtual currency to increase the community's activities is a typical approach (Sakamoto & Nakajima, 2013a), but the approach may not be appropriate for motivating diverse citizens in our society. The basic strategies are not enough to make our society flourish, but enhancing flourished crowdsourcing with the monetary reward does not solve the problem. Thus, we need alternative methods of guiding diverse citizens, who are the most essential factors in achieving a flourished society. As shown in the next subsection, for example, any aesthetic or precious object, empathetic creatures and even useful information can be used; we may also use a mechanic to influence the behavior of citizens, such that they consider that the mechanic makes their activities meaningful. In the next subsection, we introduce gameful digital rhetoric to make a variety of objects and mechanics in our space more valuable by incorporating fictionality into the real space for enhancing the basic strategies to make flourished crowdsourcing's participants more flourish. The micro-task proposal is published and disseminated to all participants by touching the common resource with the micro-task organizer's smart phone and sending a photograph that shows the current status of the resource.

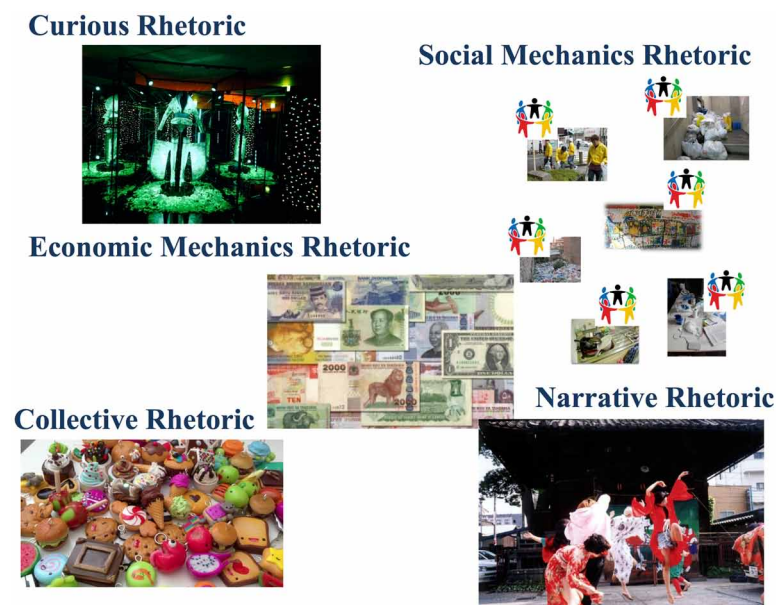
Gameful Digital Rhetoric for Designing Fictionality

The semiotic aspect of the real space is essential in discussing how the space is meaningful, such that we can discuss the meaning-making of each symbol that appears in the real space. *Digital rhetoric* in digital games, which we designate gameful digital rhetoric, often plays a role in manipulating a player's actions to advance a game. In particular, digital rhetoric that represents fictionality has a powerful influence on people in defining the meaning of the worlds of digital games, as shown in the previous section. Gameful digital rhetoric consists of two concepts: "rhetoric" and "value". "Rhetoric" is defined in the *GamiRhetoric* model, and "value" is defined in the *GamiValue* model. The design of virtual objects and mechanics based on "rhetoric" and "value" can be conceptually useful for designing meaning in the real space to influence human behavior, thinking, and feeling in smart cities. In most previous game studies, although playfulness and gamefulness are two essential components in play research, as claimed by Caillois, playfulness and gamefulness are typically competitive concepts (Deterding, 2015). Conversely, in our approach, we consider playfulness and gamefulness together to enhance the meanings in the real space. Playfulness is important in enhancing meaning in the real space to increase its attractiveness. This factor increases the intrinsic motivation of humans in their everyday lives. On the other hand, gamefulness is essential in enhancing meaning in the real space to engage people in their communities. Incorporating gameful digital rhetoric into the real space contributes to enhancing the meaning, and it makes the real space more meaningful to citizens. The incorporation of economic and social mechanics is a typical example of the use of "rhetoric". For example, encouraging communities' activities through virtual currency and increasing empathy among community members are typical cases of the use of "rhetoric". Additionally, adding aesthetic, computationally changing expressions to reflect the current situation of citizens is a typical case of the use of "value".

Gameful digital rhetoric offers multiple frames for designing and analyzing fictionality, enhancing meaning in the real space. The multiple frames defined in gameful digital rhetoric allows designers to properly frame the enhancement of the meaning in the real space from different perspectives so that designers can then focus on how to enhance the real space more meaningfully from these multiple different perspectives. Because investigating these multiple frames incorporates the Seligman's five factors as described in the previous section, enhancing the basic strategies with gameful digital rhetoric allows flourished crowdsourcing achieving to make our society flourish. Additionally, the approach can take into account the frames independently so that designers can incrementally add or replace the meaning of the real space. Meaningfulness is a crucial design factor for emotionally engaging citizens. The enhanced meaning gained through gameful digital rhetoric makes explicit the desirable lifestyle to be achieved through their activities and guides citizens in smart cities by offering many attractive imaginary and artificial benefits.

- **The GamiRhetoric Model:** The *GamiRhetoric* model abstracts the real space from the gameful aspect for designing digital rhetoric to make the digital world meaningful. It consists of five types of rhetoric: curious rhetoric, narrative rhetoric, collective rhetoric, social mechanics rhetoric and economic mechanics rhetoric, as shown in Figure 4. These five types of rhetoric have been extracted from experience based on building several crowdsourcing services, as detailed in Sakamoto, Nakajima and Akioka (2015). These authors provide further evidence of how each type of rhetoric is extracted from our experiences. In crowdsourcing infrastructures, designing social influence requires cognitive effects to be exerted on individuals. In this context, changing the meaning in infrastructures alters the cognitive effects on individuals. The five types of rhetoric noted above are used to design the meaning of these infrastructures.

Figure 4. GamiRhetoric model



Curious rhetoric influences people through people's five senses—including the visual and auditory senses, which offer us emotional engagement such as interest, happiness and comfort—and increases their curiosity to motivate their activities. Collective rhetoric represents the accumulated efforts of participants and is one of the essential motivations for participants to continue their efforts. Narrative rhetoric contains an argument specified in a narrative. A typical narrative teaches people what they should do in the everyday lives that they desire. Narratives have two aspects. The first aspect describes the ideological messages in the narrative; the second aspect relates to goal-setting in the narrative. This type of rhetoric is specific to digital games, which operate based on interaction with a player. Finally, social mechanics rhetoric and economic mechanics rhetoric offer the norms, rules and mechanics that are typically used to collectively coordinate people in the real space. They include various social and economic mechanics such as the market economy, the gift economy, the altruistic society, battle and role-playing mechanics, with these mechanics also being typical underlying mechanics used in popular digital games.

Regarding the utilization of the frame of the *GamiRhetoric* model, enhancing the meaningfulness added to each frame is important. The agency and immersion properties of this model are useful concepts that are implemented in digital games to make objects more meaningful. The property of agency relates to whether participants can control the effects on their activities, and the property of immersion refers to whether these effects reflect players' real activities without violating the realism of the enhanced real space.

- **The GamiValue Model:** The *GamiValue* model abstracts the real space from the playful aspect for designing a digital rhetoric to make the digital world meaningful. It consists of five types of value. Using value has recently been recognized as an important design approach to developing desirable digital services. In analyzing digital games, it is useful to systematically summarize what values players feel towards the digital game. These values have been extracted from user experiences with developing various digitally enhanced products. The values in the model are extracted from a semiotic perspective, and the model defines six frames for attaching the following values to virtual objects: *informative*, *aesthetic*, *empathetic*, *authentic*, *mindful* and *ideological values*, as shown in Figure 5. Sakamoto, Nakajima and Alexandrova (2015) and Sakamoto, Alexandrova and Nakajima (2015) present further justification of how values can be extracted from experiences with developing digitally enhanced everyday artifacts.

The first value is informative value. This value offers sufficient information to people and helps them make better decisions. A typical example of this value is an augmented reality service that superimposes useful information onto a video. This service provides people with detailed information on their everyday environment, such as shopping and travel information. The second value is empathetic value. This value is achieved and enhanced by adding some similarity with a user. It is usual for people to have a strong sense of empathy to people when they share some similarity between them. People can even feel a close relationship with a product that has some similarities to them. The third value is authentic value. This value provides people with a sense of ownership. In particular, physical tangibility is important because it increases people's sense of ownership of an object. For example, people enjoy owning expensive jewelry and artwork. Scarcity is key to increasing this sense of ownership because collecting rare objects increases social status. The sense of ownership of an object is very important because it allows people to create their own original "empathetic stories" with the object. These stories include people's feelings and their levels of attachment to an object and how their everyday lives have changed following their

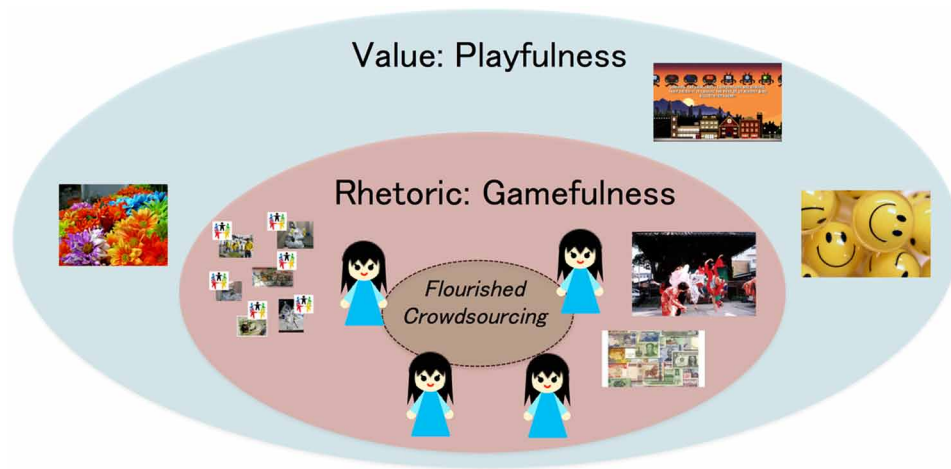
Figure 5. *GamiValue* model



possession of the object. The fourth value is aesthetic value. Aesthetics is an important concept with regard to making everyday objects more attractive. Aesthetics is a branch of philosophy that addresses the nature of art, beauty, and taste, particularly the creation and appreciation of beauty. For example, traditional Japanese folk crafts represent aesthetic values, which are important in increasing people's quality of life. The fifth value is mindful value. This value provides people with positive feedback regarding their current situations and shows the future influences of their current activities. The value is used when emphasizing the mindful and positive aspect of other values. Showing positive information should increase people's motivation to engage in desirable activities. The sixth value is ideological value. This value reminds users of important ideological concepts, such as friendship and justice. This value is not explicitly presented to people; instead, special stories that contain important ideological messages are used to implicitly explain the importance of these concepts. If people are familiar with the stories, then the characters that appear in the stories can be used as metaphors to demonstrate various ideological values.

- Design Process with Gameful Digital Rhetoric:** As shown in Figure 6, in our approach, we first consider the respective types of rhetoric in the *GamiRhetoric* model, and then, we exploit the types of value in the *GamiValue* model to make the incorporated fictionality more meaningful and realistic; this approach is proposed as rhetoric-focused design, described in Sakamoto and Nakajima (2015b), because gamefulness offers more fundamental substrates that engage citizens in an infrastructure-based approach such as flourished crowdsourcing (Sakamoto, Nakajima & Akioka, 2015). When considering each model, we analyze each frame of the model to discuss the meaning of the incorporated fictionality. With gameful digital rhetoric, a designer who designs and analyzes fictionality takes into account each frame independently and incrementally. Thus, it is easy to add and replace the respective “rhetoric” and “value” in gameful digital rhetoric

Figure 6. Flourished crowdsourcing with gameful digital rhetoric



while deploying playfulness in the real field. Thus, for typical designers, our approach is friendlier. Because gameful digital rhetoric enhances the meaning of the real space, all citizens in the enhanced space are potentially influenced through the incorporated fictionality. By replacing and adding the “rhetoric” and “value” incorporated into the space incrementally, citizens are guided to change their collective human behavior.

Incorporating Fictionality to Make the Activities of Citizens Flourish

To demonstrate our approach, the following shows a concrete story world in which fictionality is introduced in flourished crowdsourcing. As shown above, the basic design strategy of flourished crowdsourcing is to adopt an altruistic society, represented as social mechanic rhetoric. To enhance the social influence, a participant in flourished crowdsourcing plays a role in the story world. To design the story world, we adopt a design-oriented approach known as design fiction to critically design and analyze the effectiveness of gameful digital rhetoric in flourished crowdsourcing. Design fiction exploits the use of story worlds created based on the techniques of design fiction to demonstrate the possible effects of new technologies (Lindley, 2015; Tanenbaum, 2014). This section presents one example of concrete story worlds that show how citizens behave in flourished crowdsourcing. Design fictions combine elements of science fiction, science fact and design to create diegetic prototypes (Karbey, 2010), that is, artifacts that exist within the worlds of the story. Design fictions attempt to forge a discursive space by depicting technologies and the situations in which they are used that are simultaneously real and speculative. Using story worlds as a substrate to sketch these artifacts enables design fictions not only to explore concepts and technical pitfalls but also to extract insights about what it would be like to live with these technology-oriented artifacts in our everyday lives. When designing a story world to increase social awareness, we also adopt a technique known as a pastiche scenario (Blythe & Wright, 2006), which is one of the most popular techniques used in design fiction. The technique uses characters in an existing well-known story; thus, the approach easily delivers more information in a story world without a long, detailed script to make people understand the story world.

After presenting the scenario, we explain how gameful digital rhetoric is used to design fictionality in the scenario. In the scenario, fictionality is incorporated into the real space through the concept known as virtual forms (Sakamoto & Nakajima, 2014a; Sakamoto, Nakajima & Alexandrova, 2015). Virtual forms procedurally show changing fictional expressions according to the current situation and seamlessly integrate the expressions into the real space.

1. A force encroaches on the peaceful world, with each micro-community member asserting his or her power. Then, a shared table also becomes dirty. Hajime plays the role of a heroine who saves the world but is caught by a monster who destroys nature. The peaceful world suddenly becomes dreary or colorless.¹
2. Her friends Rui, Sugane, and Utsutsu are assigned roles as team members to work together to find a person who can perform a micro-task to organize the shared table and release Hajime from the monster. Hajime asks her team members to complete their quest as micro-task organizers.
3. Each team member who plays the role of micro-task supporter has a smart phone whose progress bar presents his/her contribution as an inner world. If the team cannot find a person to perform the micro-task before the deadline to save Hajime, the world will be devastated, and they will lose their powers forever.
4. Hajime's team members are aware of their powers. They notice that three independent powers are necessary to activate the ability of Tsubasa, another heroine, to accomplish the proposed micro-task as a micro-task performer. According to the team members' individual personalities, Rui's power is intelligence, Sugane's is technique, and Utsutsu's is strength.
5. Each member learns how to save the world from environmental pollution to increase his/her power. Rui increases her knowledge in various areas, Sugane learns various techniques, and Utsutsu studies the importance of political power to solve the problem of environmental pollution.
6. Tsubasa's smart phone has a progress bar showing whose power is currently given to her, and she waits to collect all three powers. Finally, all of the team members possess their powers and identify Tsubasa as the right person to perform the micro-task.
7. Once Tsubasa possesses the three powers, her smart phone informs her that it is the right time to perform the micro-task, and she can finally clean the table. Rui, Sugane, and Utsutsu observe that Tsubasa has completed the micro-task because their inner worlds revert to the original peaceful world where many flowers bloom. She finally sends photos to other members to notify them of the completion of the micro-task.
8. Hajime is released from the monster, and the monster departs for her galaxy. She appreciates Tsubasa and her team members and that the world is again bright and clean. Now, Rui, Sugane and Utsutsu also have knowledge and know the techniques to avoid environmental pollution. On the next occasion, they will want to contribute to other micro-tasks to achieve a desirable society.

In the above scenario, the desirable situation is defined only in the story world. If the story world is not well delivered to citizens, they do not understand what their desirable situation is. Additionally, the progress bar does not offer a visual metaphor to show how they are to achieve a desirable situation; it is desirable to explicitly offer the desirable situation and participants' progress as more meaningful representations. To overcome this issue, collective rhetoric is added to the approach to increase the intrinsic motivation of individuals. We adopt virtual forms to seamlessly incorporate collective rhetoric into flourished crowdsourcing. In the scenario, flourished crowdsourcing adopts three virtual forms, as shown

in Figure 7. The first virtual form shows our fictional everyday environment. When a monster appears, the expression showing fictional nature becomes colorless. In the story world, the monster represents a concrete symbol of environmental pollution, which facilitates reminding participants that pollution is a serious problem in our society. The second virtual form is shown on each team member's mobile phone and represents his/her inner world. The virtual form is used to show each participant's current contribution as an enhanced progress bar. The third virtual form shows an enhanced progress bar of the growth of the power of each team member and a deadline for a micro-task performer to complete the micro-task.

When designing virtual forms, we take into account several values. The most essential value is aesthetic value because most people can easily understand that the aesthetic is lost when they do not feel that they are flourishing. Both the first and second virtual forms use natural landscapes because it is easy for them to represent aesthetic value and landscapes become metaphors that represent a flourished society. In the first virtual form, empathetic value is adopted in a negative manner. The monster is represented as a less empathetic creature; thus, citizens easily understand that the monster is violating the natural landscape. Finally, the third virtual form uses mindful value and informative value. The virtual form shows how many people agree to support the activity. Additionally, the visual represents the positive effect from when they agree to support the activity. The most important aspect of these designs is that the virtual forms make the desirable situation and achievement of citizens more meaningful, although they are not clearly meaningful without introducing these virtual forms.

Current Status and Analysis

We have developed a flourished crowdsourcing prototype system to demonstrate the feasibility of our idea. The prototype system consists of the following three components. The first is an Android phone that possesses an NFC reader, as shown in Figure 8. The second is a computer that is connected to a server—designated the resource management server—embedded in a small, common resource. The last component is a server that stores various data related to the flourished crowdsourcing activities in

Figure 7. Virtual forms in flourished crowdsourcing

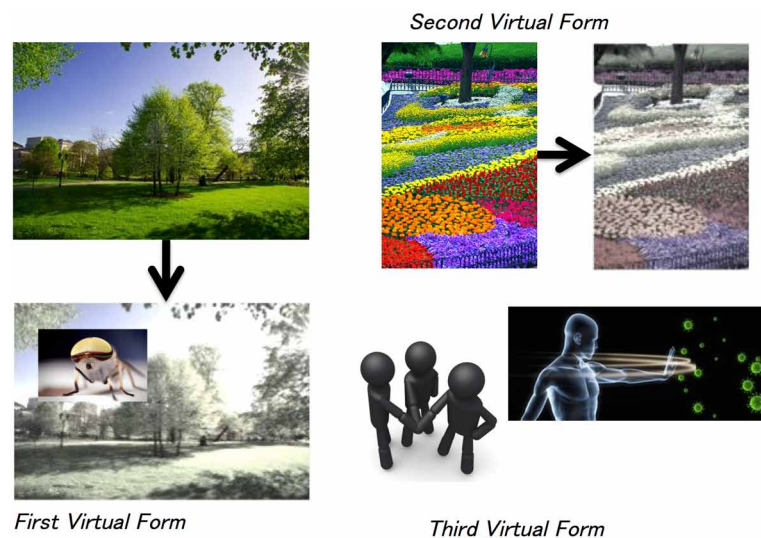


Figure 8. Flourished crowdsourcing prototype system



a database. This second server is designated the flourished crowdsourcing server, which is networked to all of the resource management servers. The system has been implemented as an HTML5 (World Wide Web Consortium, 2014) web application. Thus, participants can easily begin using the flourished crowdsourcing service with minimal effort. In the current prototype system, we have also installed several public displays to show the computationally changing fictional expressions in public spaces as virtual forms, as shown in the previous subsection.

Currently, we have deployed our prototype systems in our laboratory environment and conducted some experiments to investigate the feasibility of flourished crowdsourcing. The current focus of flourished crowdsourcing is to achieve sustainable environments. Each micro-task organizer proposes a micro-task such as cleaning a desk or sink in our laboratory or moving tables or chairs to make us more comfortable staying in our laboratory. Our current prototype system deployment focuses on how social influence is changed by incorporating fictionality within a small community. From our experiments using the prototype system, we have found that a micro-task organizer's creativity becomes a key to increase the activities of laboratory members because other members may not know what activities contribute to making our laboratory environment sustainable. It is also important to exploit the altruism among the members of the laboratory because people typically like to help well-known people from whom they feel a good impression. In the prototype system, each participant chooses a popular virtual character as his/her avatar that all of the participants know well and typically favor. We also adopt scenario analysis to discuss the effect of embedded fictionality on social influence. From our experiences with the prototypes system, the investigation of the effect of the social and economic mechanism incorporated in flourished crowdsourcing can be performed based on the prototype implementation because participants need tangible experiences to effectively find the drawbacks. However, to investigate different approaches to incorporating fictionality, it is not easy to perform real experiments for the all of the possible investigations on the prototype systems. Thus, scenario analysis compensates for the prototype implementation to accelerate finding the potential pitfalls of the respective strategies.

Here, we present the analysis of the basic mechanism of flourished crowdsourcing based on a concept known as social influence (Cialdini, 2006). In flourished crowdsourcing, the social mechanic rhetoric is the most fundamental and most commonly offered as a basic mechanism, as shown in the previous subsection. The social influence known as social proof is crucial in altering citizens' behaviors. In the basic mechanism, each micro-task supporter's contribution is visualized on his or her smart phone so that notifications regarding people's contributions guide others to participate in flourished crowdsourcing activities. However, there is the possibility that no one will contribute to the activities—a phenomenon known as social loafing. Therefore, it is important to add another mechanic to guide contributors to join in activities as early contributors. Competition among participants also increases the effect of social proof. In the current narrative, a progress bar is introduced to show the contributions of others to the micro-community. When a participant feels that his or her contribution offers a visible benefit, he or she feels that the service is meaningful. The progress bar must show who contributes to current activities, and that person should be an acquaintance of the recipient.

This analysis assumes that the participants in a micro-task belong to the same community. The setting has a significant influence on participants' behaviors because the social influence known as reciprocity (Cialdini, 2006) typically affects community members. Thus, when a micro-task organizer is an influential community leader who contributes significantly to the community, other members are likely to participate in additional flourished crowdsourcing activities. However, in the real space, citizens may not be members of the same community. In this case, the story world must be enhanced to exploit reciprocity among strangers.

The above analysis indicates that only the basic mechanism does not engage citizens to make their society flourish. Our approach to overcoming this drawback is to adopt the role-playing concept, as shown in the above story world. Role-playing for incorporating fictionality in flourished crowdsourcing can be introduced through narrative rhetoric and curious rhetoric. Each participant's role is introduced through curious rhetoric; the relationship among the different roles is defined through narrative rhetoric; a story world defines their relationship. In our case, using pastiche scenarios is crucial in avoiding an increase in the size of the script that presents the story world. To make fictionality more meaningful, curious rhetoric needs to offer aesthetic value or empathetic value; if a citizen plays an aesthetic or empathetic role, the possibility of other citizens helping him/her will be significantly increased. Using pastiche scenarios easily increases the empathetic value of the roles.

In the story world, narrative rhetoric offers ideological value and informative value. In particular, ideological value is essential to increase citizens' intrinsic motivation to achieve an offered challenge because the value makes the challenges more meaningful and interesting to them. In this case, using pastiche scenarios is also an essential factor in incorporating ideological value because the ideology embedded in the story world in which the character in the pastiche scenarios appears easily reminds us of the aim of flourished crowdsourcing activities through role-playing (Sakamoto & Nakajima, 2013b). On the other hand, informative value is important because this value helps participants make better decisions oriented towards a desirable situation. This type of value also provides effective visual or sound effects to make them more positive. Thus, it is possible to embed mindful value through the effects. If role-playing offers the illusion of knowing each other well and each citizen plays a different role with regard to who should independently perform his/her challenges to realize the desirable situation specified in the story world, then the problem described in the analysis can be overcome. Additionally, the approach also supports Seligman's remaining factors: positive emotion, relationships and meaning. It is possible to make citizens flourish.

DESIGN IMPLICATIONS

Making our society flourish requires diverse citizens to increase their awareness of the necessity of making our society flourish. Traditional approaches in gamification and persuasive technologies typically focus on the average effects on changes in human behavior. However, in contemporary modern society, most people have become “interested bystanders” who do not take any action to influence our everyday lives (Krontiris, Webb, Krontiris, & Chapman, 2015). The existence of a large number of free riders significantly decreases the motivation of active participants and hinders the flourishing of our society. However, as shown in Akasaki, Suzuki, Nakajima, Yamabe, Sakamoto, Alexandrova and Nakajima (2016), traditional gamification-based approaches can approach only a part of the diverse range of people. In particular, the majority of people are typically not taken into account in these approaches. To guide the collective human behavior of diverse citizens, it is essential to enhance the meaning of the real space incrementally by adapting to diverse citizens. As shown in the previous section, gameful digital rhetoric allows designers to incrementally enhance meaning by adding or replacing values to the rhetorical frames designed in the *GamiRhetoric* model. Conversely, traditional approaches such as gamification and persuasive technologies are difficult to replace and it is difficult for them to add game mechanics or persuasive strategies on-demand because these approaches focus on motivational mechanisms to change individual human behavior and do not offer a mechanism for framing the design for changes in collective human behavior.

Dunne and Raby (2013) claim that design offers new forms of expression for complex and critical issues; these forms of expression are grounded in the most abstract, speculative and future-focused considerations. Critical questions about emerging technology in everyday situations have presented preferable futures as opposed to predicting the future. They designate the design approach speculative design. Forms of speculative design can be adopted in designing the fictionality presented in our approach to increase the awareness of complex social phenomenon. For example, taxes play an important role in achieving a sustainable society, but for many people, it is difficult to understand how the current tax mechanism influences our sustainable society; however, well-designed works based on speculative design effectively influence human behavior. Additionally, some psychoanalytical frameworks such as those in Segal, Williams, and Teasdale (2002) and Gunaratana (2001) show the necessity of increasing self-awareness to make people happy. Their approaches propose effective techniques to increase our happiness, although at present, the relationship with the approach of positive psychology is not clear. The approach increases each citizen's self-efficacy in realizing self-fulfillment; direction helps diverse citizens take note of the awareness of our surrounding environments. One of drawbacks of our current approach is that citizens may significantly lose interest if the incorporated fictionality does not contribute to our real everyday lives. Finding the balance to observe self-awareness in the incorporated fictionality is essential in making our approach successful.

Incorporating fictionality into flourished crowdsourcing by assigning fictional roles to community members motivates them to propose and complete a micro-task oriented towards a desirable situation defined in flourished crowdsourcing if a fictional story presents ideological messages that identify the micro-task's importance in achieving a desirable situation (Sakamoto & Nakajima, 2014b; Sakamoto & Nakajima, 2015a). Because the real space can be represented abstractly and sometimes ironically in a fictional story through framing to simplify or exaggerate essential and important concepts in our everyday lives (Sakamoto & Nakajima, 2014a), people easily observe the concepts that are relevant to achieving an ideal, sustainable society. Fiction also allows citizens to use metaphors that are more

appropriate than documentaries or other types of nonfiction. In particular, Japanese animation stories contain complex ideological social messages oriented towards futuristic lifestyles (Sakamoto & Nakajima, 2014a; Sakamoto & Nakajima, 2014b) to increase people's intrinsic motivation. These stories can offer many effective metaphors to increase our self-efficacy through the positivity that they express. This approach also allows flourished crowdsourcing to incorporate ideological value alongside other values (Sakamoto, Nakajima & Alexandrova, 2015)—and improves on our current approach in a manner similar to a pervasive game that blurs the spatial, temporal, and social boundaries between fiction and reality by making the magic circle disappear (Montola, Stemros & Waern, 2009). This approach can be used to inform citizens of the importance of flourished crowdsourcing activities.

The *GamiRhetoric* model and *GamiValue* model currently offer some frames for helping us design an enhanced real space. The number of frames offered in gameful digital rhetoric should be as minimal as possible. However, we still need to consider whether the number of frames needs to be increased. The current frames are extracted from our previous case studies (Sakamoto, Nakajima & Alexandrova, 2014; Sakamoto, Nakajima & Akioka, 2015). We carefully justify these frames and avoid the temptation of adding new convenient frames in an easy manner. As shown in Sakamoto and Nakajima (2015b), there are several promising candidates that may be added as a new frame, and we still need to investigate the issue. In Ishizawa, Takahashi, Irie, Sakamoto and Nakajima (2015), we are also working on an alternative model to discuss a design framework to develop a virtual or enhanced world. The model offers seven frames to help us more meaningfully design the enhanced space. As the next step, we also need to investigate how the model can be integrated into gameful digital rhetoric.

The user study of the prototype system shows that the narrative offered from the first-person perspective is more effective than the narrative from the third-person perspective (Sakamoto, Nakajima & Alexandrova, 2015). The approach offers a new possibility of guiding people to exploit a concept known as transmedia storytelling (Sakamoto & Nakajima, 2015a). In transmedia storytelling, one part of an entire story is fragmented in different media placed in various locations in the real space. Each micro-community can create its own favorite partial story to play a role in participating in flourished crowdsourcing activities. The approach engages citizens to become activists to make our society flourish. However, the approach requires maintaining consistency among multiple partial stories created by the independent micro-communities. If consistency is violated, then the activities performed by one micro-community may interfere the activities performed by other micro-communities. Fan culture, especially popular culture, is important; various fans with different purposes and preferences have developed consistent stories (Lamerichs, 2014). The most important issue to maintain consistency is to offer all participants a shared view of the world and the roles of each fan in the world. As the next step of our project, we would like to exploit this issue to improve the current status of flourished crowdsourcing.

We also need to investigate when and how citizens feel happiness in their everyday lives. OECD (2015) has reported the measurement of human well-being in each country by using standard questionnaires. The approach is based on long-term research on human well-being from the psychological perspective and allows us to quantitatively measure human well-being. Thus, the approach enables us to quantitatively evaluate the effect of political strategies. However, we still have questions concerning why citizens feel happy. Quercia, Schifanella, and Aiello (2014) have developed a service to show a route to a destination where a person will feel happy. The service collects numerous photos taken by crowds in urban cities and marks whether people feel happy. Then, based on where most people mark the photos taken along the route as happy, the service finds routes. This approach opens a new direction because we can automatically collect a variety of information about how people feel happy from crowds of citizens. In

our current approach, the choice of “rhetoric” and “value” relies on the designers’ instincts. Therefore, there is the possibility that a designer’s assumption is completely wrong. Using the power of crowds to design fictionality is a promising direction. Gushima, Aikawa, Sakamoto, and Nakajima (2016) report one approach to delving into this issue. However, as reported in the paper, we still need to consider whether we can develop creative fictionality that attracts citizens and maintains their interest for a long period of time from the approach.

CONCLUSION

Our everyday lives have become increasingly complex. The current progress in developing smart cities helps us have a more comfortable lifestyle because a variety of forms of automation in smart cities reduces the complexities in our real space. However, as described in this chapter, simply reducing complexities in terms of resource efficiency does not create a truly desirable lifestyle for citizens. We believe that directing human attitudes and behaviors towards a more flourishing lifestyle is more important. This chapter introduces a social information infrastructure designated flourished crowdsourcing, a smart city infrastructure for engaging people towards a flourished society, and demonstrates the design concepts for guiding people in flourished crowdsourcing. In particular, our approach increases the social influence within communities and makes us aware of the necessity of the activities through incorporating fictionality in the real space.

Flourish crowdsourcing offers a bottom-up approach to solving serious social problems to increase our human well-being. Citizens are guided on what they need to do to make themselves happy by increasing their self-awareness to achieve a flourished society. However, we still need to investigate the role of governments and companies in helping citizens to voluntarily make their society flourish. In particular, in a modern society, our universal value system is based on a monetary system, and money remains the essential incentive for motivating people to perform the uninteresting activities that are required to make our society flourish. The governmental system is also essential in coordinating communities that have conflicting opinions without a problem owing to the tragedy of the commons and in fairly dividing assets among citizens without concentrating the world’s wealth. We will investigate how to coordinate the economic and governmental systems with the social infrastructure to guide citizens in making their society flourish from the bottom-up in the next step.

We also need to discuss the ethical issues of modifying human attitudes and behaviors because, if misused, the approach makes it possible to unintentionally or maliciously control people. We will investigate the issue by introducing a concept known as the *magic circle* (Montola, Stemros & Waern, 2009), which is widely used in game studies to discuss the ethical issues.

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ENDNOTE

- ¹ The characters in this story world are derived from an animation in Tatsunoko Production (2011).

Chapter 13

Public Perception Spatial Data from the PPGIS Jaguarão Experiment

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ABSTRACT

This chapter addresses PPGIS (Public Participation Geographic Information Systems), a participatory method through which the public can produce maps and spatial data that represent their perceptions of the urban space in question. Specifically, it analyzes the data collected from an experiment in Jaguarão, Brazil. The data represents the perceptions of a small group of inhabitants about the problems and potential of the city's urban area. The procedures include an exploratory analysis and data visualization in the form of maps that allow describing a variable's distribution and identifying patterns. Moreover, for some issues, the authors cross the perception collected data with infrastructure data, socioeconomic data, and cadastral data to study possible associations among these different types of information layers. The results show that public perception, collected through PPGIS, forms an additional information layer that could be analyzed together with other information layers commonly used in urban planning, and thus to be taken into account for designing better cities.

INTRODUCTION

Cities are complex organizations, and therefore the production, use, and exchange of spatial knowledge in various forms are essential processes for its planning and management (Rocha & Pereira, 2011; Pfeffer et al., 2012). It is from the confrontation between inhabitants' knowledge, subjective and difficult to generalize, and experts' knowledge, objective and abstract, that a better comprehension of a given territory arises (Friedmann, 2007; Joliveau, 2008).

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But the planning system is still mainly based on the technical approach, which emphasizes accurate and unambiguous information. Urban planning in general uses only official data, in which aggregated statistics are the only way to take people into account (Friedmann, 2007; Brabham, 2009). Experts' knowledge is dominant in urban planning, given that planners have the power to choose which knowledge to use and how to use it, and this choice is almost always based on those experts' own professional values (Rantanen & Kahila, 2009). According to Wallin & Horelli (2012), it is difficult to move from a planning system dominated by specialists to one that gives voice to different stakeholders.

Knowing how to analyze and use inhabitants' knowledge consistently in urban planning is a crucial issue (Kahila & Kytä, 2009; Brown & Reed, 2009). Knowledge integration therefore is an aspiration for a deeper and more impactful participatory planning (Brown, 2012a). The democratic potential of participatory planning is challenged when it fails to incorporate inhabitants' knowledge significantly (Brabham, 2009). But so far, in general, planners have failed to address the perspective of the population consistently in urban planning (Talen, 2000; Corburn, 2003; Rantanen & Kahila, 2009; Brown & Reed, 2009).

The growing emphasis on participatory processes puts pressure upon planners to find new ways of combining their expertise with the knowledge that only inhabitants have (Van Herzele & Van Woerkum, 2008). However, involving the public in urban planning is not a straightforward task. As Forester (2006, p. 447) states: "Easy to preach but difficult to practice, effective public participation in planning and public management calls for sensitivity and technique, imagination and guts." In spite of pro-participation laws and the widely accepted discourse that this is the right thing to do (Taylor, 1998; Innes, 1998), the reality is that many of the supposed benefits of participation are not being achieved (Innes & Booher, 2004; Klessmann, 2010).

At the same time, the citizens and the cities are becoming smart "in ways that enable us to monitor, understand, analyze and plan the city to improve the efficiency, equity and quality of life in real time" (Batty et al., 2012, p. 2). Digital tools are becoming ubiquitous in everyday life and have high potential for the collection of socio-spatial and temporal data. The emerging urban environments are completely different from anything that has been experienced so far. It is a new context, where a much larger group of citizens can engage (Rocha & Pereira, 2011; Pfeffer et al, 2012.). Soon, most of the data to be used to understand the cities will come from personal transactions, challenging the static models of data collection and interpretation commonly used in urban planning (Batty et al., 2012).

Thus, distinguished authors advocate the need for a reformulation in urban planning through the use of technologies that enable the creation of more interactive and collaborative techniques and methodologies (Hansen & Reinau, 2006; Yigitcanlar, 2006; Brown & Reed, 2009; Horelli, 2013). According to Batty et al. (2012, p. 4): "new sources of urban data (...) and all the apparatus used in engaging the community in developing smart cities require new forms of online participation making use of the latest ICT in terms of distributed computation."

In this regard, recent technological advances around Information and Communication Technology (ICT) and Geographic Information Systems (GIS) include new perspectives. Noteworthy among such advances are the interaction provided by social networks, the easy access to information and knowledge, the sophisticated tools freely available, the increased interactivity between users and systems, and the ubiquity of geographical information (Jazayeri, 2007; Batty et al., 2012). In addition to sensor networks, interactive interfaces in public spaces, and mobile devices, in the smart city.

Nowadays people not only consume content by downloading information but also contribute and produce new content by uploading information on the Internet (Vossen & Hagemann, 2007). Before,

planners and professionals were the only producers and users of information on urban issues; now, however, inhabitants are also coproducers of urban information through the massive use of digital tools (Talen, 2000; Batty et al., 2012). In this context, planners will have to reconsider their ways of working and the methods through which planning information is created, distributed, processed, and used (Stafans et al., 2010).

If the Internet is the primary means of exchanging information and communication, GIS are a technology that plays an important role in collecting, processing, and dissemination of spatial information, and most of the information necessary for public policy formulation has a spatial component (Sieber, 2006). To Yigitcanlar (2006), the effective use of ICT and GIS in urban planning represents the possibility of establishing a permanent system of public involvement in planning.

PPGIS BACKGROUND

PPGIS (Public Participation Geographic Information Systems), as the name suggests, use GIS tools for public participation, connecting the technical capacity of GIS to local knowledge (Sieber, 2006). The public participates by producing maps and spatial data that represent their perceptions of the urban space in question.

The term is used to cover a range of topics related to GIS and society, and it is therefore difficult for scholars to reach a consensus on its definition. Dunn (2007) suggests to look at the dimensions that differentiate PPGIS from conventional GIS. According to the author, PPGIS arose from the recognition that traditional GIS represent a simple world view in two aspects: the type of information that is fed in and consequently underpins decision making and the limited sources of that information. Regarding the information type, a possible understanding of PPGIS is as a means of integrating inhabitants' knowledge with expert data, which provides the opportunity for alternative visualizations of space, place, and reality. Regarding the information source, PPGIS implies the extension of the term "user" to include the "public", incorporating the concept of "public participation" commonly used in planning. One can therefore affirm that the PPGIS method involves local communities creating information to be fed into a spatial GIS database and later used in decision making on spatial issues affecting those communities (Dunn, 2007).

PPGIS emerged in the 1990s from reflections about GIS and their interface with society. Some criticisms had arisen about social and cultural information exclusion, reinforcement of top-down "expert" analyses, and limitation of information access to selected groups (Cinderby, 1999). In the early 2000s, PPGIS were considered an evolution of classic participatory methods (Carver, 2001), but enthusiasm began to decline around 2005, when the literature raised several problematic issues (Poplin, 2012), such as too much concern with developing increasingly technological platforms and the recognition that terms and concepts like "participation," "public," and "empowerment" were used uncritically (Hall et al., 2010).

Then, almost simultaneously, map mashups (the mixture of different types of software and data) and collaborative mapping emerged with Web 2.0 (Batty et al., 2010). Soon, new PPGIS experiences took advantage of the online mapping trend and public awareness of geographic information (e.g. Hall et al., 2010; Bugs et al., 2010). Such projects showed the increasing interest of citizens in using participatory tools based on online maps (Poplin, 2012).

Since the beginning, the range of applications for PPGIS has been extensive. Consequently, there is no single PPGIS method but rather a variety of methods based on different approaches, goals, and

concepts (Dunn, 2007; Brown & Kyttä, 2014). Some examples of PPGIS applications after Web 2.0 (around 2005) can be found in Nyerges et al. (2006), Hall et al. (2010), Bugs et al. (2010), Poplin et al. (2012), and Kyttä et al. (2013). For an extensive review of PPGIS applications and methods, see Sieber (2006), Dunn (2007), and Brown and Kyttä (2014).

One approach adopted by researchers with many studies in the area (see a list in Brown and Kyttä, 2014) assumes that humans are active participants in their environment (thinking, feeling, and acting), leading to the meaning attribution and valuing of specific places. The group headed by Kyttä investigated the relationship between the physical and spatial characteristics of built environments and the behavior of people, focusing mainly on the application of methods to analyze and test built environmental quality by its users. Following this concept, participation connects to the idea that to create better environments, it is necessary to investigate how people experience places (Reis & Lay, 2006). PPGIS, in this case, are the tool used to collect location-based evidence from inhabitants concerning local experiences and behavior patterns (Kyttä et al., 2013).

Apart from a few exceptions (find in Brown & Kyttä, 2014), PPGIS are still relatively unexplored from the urban planner's perspective. Most of the existing experiments were developed by geographers, focusing on producing participatory mapping, or by professionals of information technology, focusing on technological development. Examples of the usage of PPGIS as an integral part of planning practice are still more scarce. An exception is Finland, where the mainstreaming of PPGIS has already happened (Kahila, 2015). PPGIS was used for example in Helsinki master plan process as one of the tools for participatory planning and a large scale dataset from nearly 4.000 participants was collected (Kahila et al. 2015). To spread this kind of practice, it is important to research about the use of PPGIS in different contexts.

As highlighted by Brovelli et al. (2014), the best conditions for holding PPGIS projects emerged with the advent of Web 2.0 and its bidirectional approach based on user-generated content, usability, and interoperability. This context presupposes innovations in PPGIS applications. Thus, aiming to extend existing empirical knowledge about the method, the purpose here is to analyze the spatial data collected in a PPGIS experiment in Jaguarão, Brazil, where PPGIS experiences are rare, and evaluate its ability to collect public perceptions and facilitate their incorporation into urban planning practices. The authors follow Brandt's (as cited in Dunn, 2007) guidelines for PPGIS evaluation: the value of the results lies in their ability to provide useful, proper, and timely information that civil and governmental organizations can use.

Moreover, there are three types of data in use for urban planning, commonly: physical-territorial data (e.g., elevation), socioeconomic data from census surveys, and cadastral data related to built environments (Ramos, 2005). Assuming that knowledge collected with PPGIS could feed a spatial database with public perceptions (Kahila & Kyttä, 2009), the authors' hypothesis is that public perceptions could form a fourth dimension in spatial databases for urban planning.

METHODOLOGY

Developed at Aalto University, SoftGIS is a PPGIS method that allows the study of inhabitants' location-based experiences (Kyttä et al., 2013). The term "soft" refers to the qualitative and subjective nature of the attributes mapped by participants, in contrast to the "hard" geospatial data layers generally associated with GIS. The method has already been applied in more than twenty cities in different countries (see a

list in Brown and Kyttä, 2014). Basically, it consists of an online questionnaire upon an interactive map interface, where users answer predefined questions by marking points, lines, or polygons on the map. Thus, the answers reference to locations and can be discharged into table formats (.csv or .xls) and shapefiles.

Thanks to a do-it-yourself interface (Figure 1), SoftGIS was easily customized for an experiment in Jaguarão, Brazil, here called PPGIS Jaguarão (Bugs, 2014). This type of interface allows anyone, even those without programming skills, to build a web application. The main technical requirements for the implementation of PPGIS Jaguarão were a server that supported the programming language and the technologies used by SoftGIS, a web browser, Internet access, and GIS software to store and analyze collected data.

Jaguarão is a border municipality located in the southernmost state of Brazil, Rio Grande do Sul, with around 28,000 inhabitants (Figure 2). It is connected to Uruguay by a river and an international bridge, producing a hybrid culture, maintaining permanent exchanges with Rio Branco, an Uruguayan municipality, well visited for its free shops. Additionally, Jaguarão is experiencing significant urban growth with new attraction poles (e.g. the Federal University of Pampa), and, in 2011, the entire central area, including about 650 buildings, was listed by the National Historical and Artistic Heritage Institute, configuring challenges for urban planning and management. In this scenario, the problem of management and urban planning becomes fierce, being necessary to develop new knowledge and skills for managers, urban planners and other social actors involved in urban policy.

In 2013, a university extension program (PROEXT) from the Federal University of Pelotas (UFPEL), located near Jaguarão (140 Km), entitled “Urban development in Jaguarão: expanding knowledge frontiers,” took place.¹ PROEXT aimed to identify weaknesses and potentials of the urban city area based on public perceptions and the public’s wishes for future urban planning. It configured an excellent institutional context for the Jaguarão experiment, wherein PPGIS tools were applied in a practical situation

Figure 1. SoftGIS do-it-yourself interface
(Maptionnaire, 2014)

The image shows a web-based configuration window titled "Edit page element" with a close button (X) in the top right corner. The window is divided into two main sections. The first section contains two dropdown menus: "Element type" with "Point" selected, and "Color" with "Blue" selected. The second section is titled "Button text" and contains a text input field with the text "Favorite place". At the bottom of the window, there are two buttons: "Close" (teal) and "Save" (green).

*Figure 2. Jaguarão location
(Wikipedia)*



by external partners, configuring an exploratory experiment. In other words, one could apply and test PPGIS in Brazil, where it is quite novel approach, at a real-world study on a real-world case.

PPGIS Jaguarão had 24 questions, 2 for each of the 12 specific planning topics that predicted marking places on the map (Figure 3), 2 general questions (“What are the priorities for the city in the future?” and “What are the city’s biggest problems?”), and a brief respondent characterization. The 12 specific planning topics were: 1) environment, 2) urban growth, 3) social housing, 4) productive activities, 5) free trade zone, 6) urban zoning, 7) density, 8) informal activities, 9) chromatic structures, 10) aesthetics, 11) mobility, and 12) equipments and infrastructure. The PROEXT team choose the topics and formulated the questions that better fit to their methodology of participatory diagnosis focused to socio-spatial issues: identifying potential problems and constraints and recommendations; selecting priorities; and socializing concepts of the city.

Being an online participatory tool, PPGIS Jaguarão was released on the Internet and social networks over three months (May to August 2013). The authors expected that participants would share the link, as happens with much of the content on the Internet. Thus, the sample was random and there was no way to establish a return rate. In addition, the PROEXT team held two workshops in public schools (Figure 4 left) and the authors also used social networks to give feedback, as recommended by the literature (Al-Kodmany, 2001; Fischer, 2011) (Figure 4 right).

Public Perception Spatial Data from the PPGIS Jaguarão Experiment

Figure 3. PPGIS Jaguarão interface for the environment topic (Bugs, 2014)

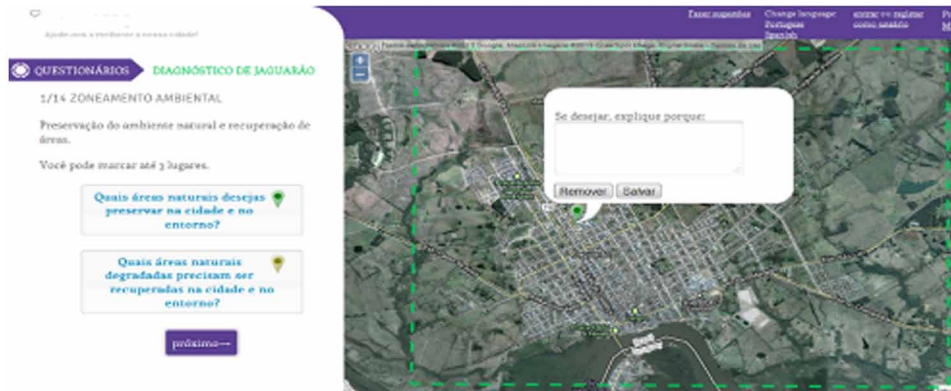


Figure 4. Workshop held at a public school (left) and Facebook webpage (right) (Viana et. al., 2013)



In total, 61 people participated, but less than half (27) provided personal information. Of these, most were between 20 and 59 years old (74.1%, 20 of 27) and university educated (59.3%, 16 of 27), similar to the profiles of other PPGIS studies (e.g. Poplin, 2012; Brown, 2012b). As for familiarity with interactive online maps, such as Google Maps, the majority, 92.5% (25 of 27) claimed to be familiar. Regarding familiarity with participatory processes, 62.9% (17 of 27) had been involved in participatory activities before. For the spatial analysis, the authors considered all users who used the online map consistently, not disregarding any of the collected spatial data.

The participants could mark up to three locations per question and provide additional text comments, if desired, in the windows that opened after users marked points on the map (Figure 3). The participants marked 955 places on the map, of which one third received text comments. There was a gradual decline in the number of responses beginning with the middle questions of the questionnaire to the end. This drawback is also reported by other studies (e.g. Poplin, 2012), suggesting that one should balance the questionnaire extension as much as possible.

The authors analyzed the data using GIS software. The goal was to measure properties and relationships, taking into account spatial location phenomena. First, the procedures included an exploratory analysis and data visualization, through mapping, describing the study variables' distribution in an attempt to find patterns. Subsequently, in some cases, the authors studied the PPGIS data collected ('soft data') by relating it with infrastructure data, socioeconomic data, and cadastral data ('hard data') to study relationships, or lack thereof, among these different types of GIS layers. The objective was to test if public perceptions could form an extra data layer in a spatial database for urban planning, i.e. look at the 'soft data' with the same weight and importance.

Most questions of the PPSIG Jaguarão asked for marking points on the map. In the point pattern analysis, the object of interest is the proper location of events. To some extent, it is assumed that each point is a polygonal area, but with unknown size and shape (Brown, 2012a). A participant may refer to an area the size of a football field, while another may refer to an area as big as a neighborhood, for instance. Thus, the data analysis was based on spatial point aggregation to delineate areas of concentration. In some specific questions, as in the city center delimitation, participants drew polygons. In this case, the analysis was the overlapping of several answers to arrive at a synthesis of defined areas.

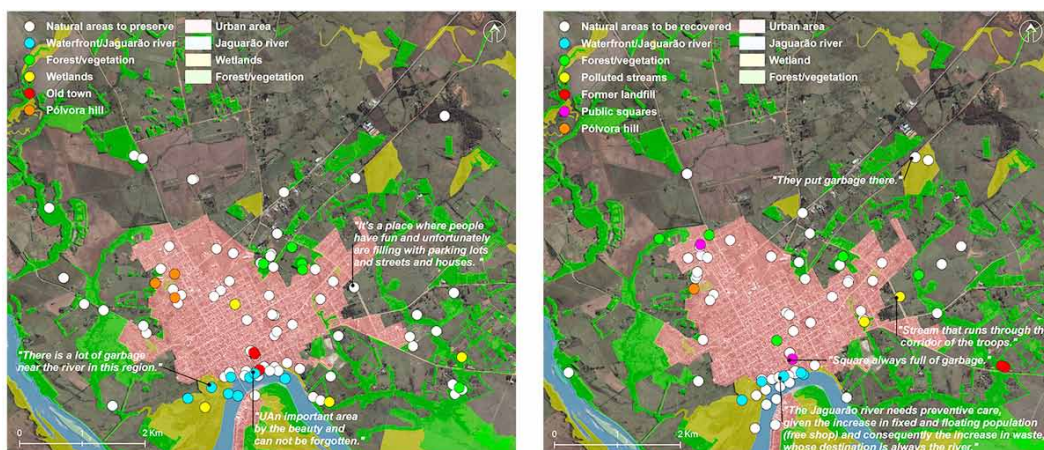
RESULTS

Following, the maps generated with the data collected for each one of the twelve topics are presented and analyzed.

Environment

Figure 5 (left) shows the places marked by participants as natural areas to be preserved in the city and its surroundings. One can see the points concentrating along the Jaguarão river. The most often cited areas in the comments have been² the waterfront/Jaguarão river (9 of 29), forest (6 of 29), wetlands (4

Figure 5. Natural areas to be preserved (left) and to be recovered (right)
(Bugs, 2014)



of 29), old town (3 of 29), and Pólvora hill (3 of 29). Figure 5 (right) shows the places marked in natural areas that need to be recovered. The most often cited areas have been the waterfront/Jaguarão river (6 of 23), forest/vegetation (5 of 23), former landfill (2 of 23), polluted streams (2 of 23), and public squares (2 of 23). Therefore, one can affirm that there is great concern regarding the preservation and recovery of the Jaguarão river as well as wetland areas located west of the international bridge connecting Brazil and Uruguay.

Urban Growth

Figure 6 (left) shows the places marked as being the best areas for new settlements. In the comments, the most cited areas have been vacant urban areas (6 of 16), areas close to the Federal University of Pampa (4 of 16), areas near the Federal Institute of Education, Science and Technology (IFSUL) (4 of 16), and areas toward the road (2 of 16). By visual analysis, it is clear that there are points concentrated in the periphery and even outside the city limits, coincidently areas with lower land value. On the other hand, Figure 6 (right) shows the places marked in areas where there are existing problems caused by urban growth. In the comments, the most often cited problems have been infrastructure (9 of 18), flooding (4 of 18), and river pollution (3 of 18). From the information overlay about existing and projected sewage networks, one can see that many of the points marked as problems are in areas without sewage systems. This means that urban expansion has surpassed infrastructure provision on the city outskirts.

Social Housing

Figure 7 (left) shows the points marked as being suitable social housing areas. The reasons for choosing these areas include good accessibility and infrastructure (5 of 20), existing social housing (5 of 20), and the existence of vacant urban areas (5 of 20). Overlaying inhabitants' average income makes it clear that the areas coincide predominantly with lower rates. Figure 7 (right) shows the places marked as areas with housing problems. In the comments, respondents highlighted the following problems: excessive density

Figure 6. Best areas for new settlements (left) and problems caused by urban growth (right) (Bugs, 2014)

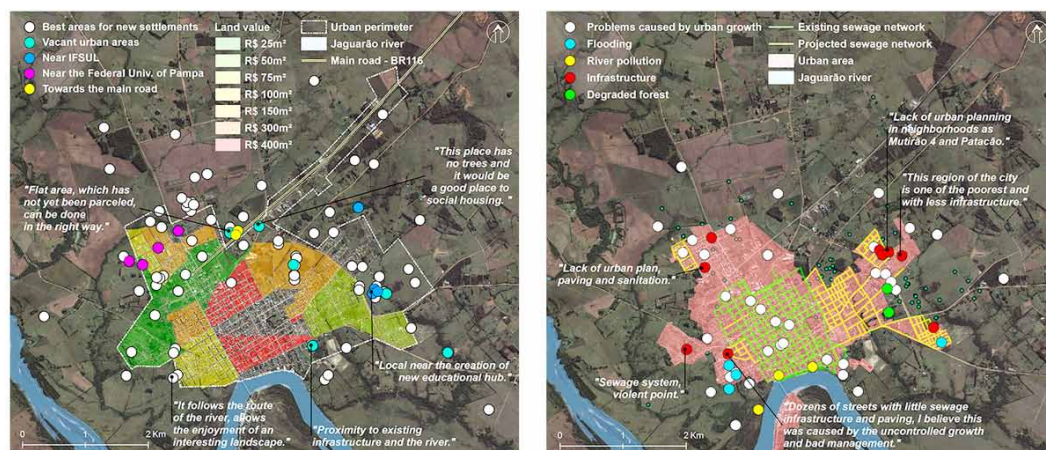
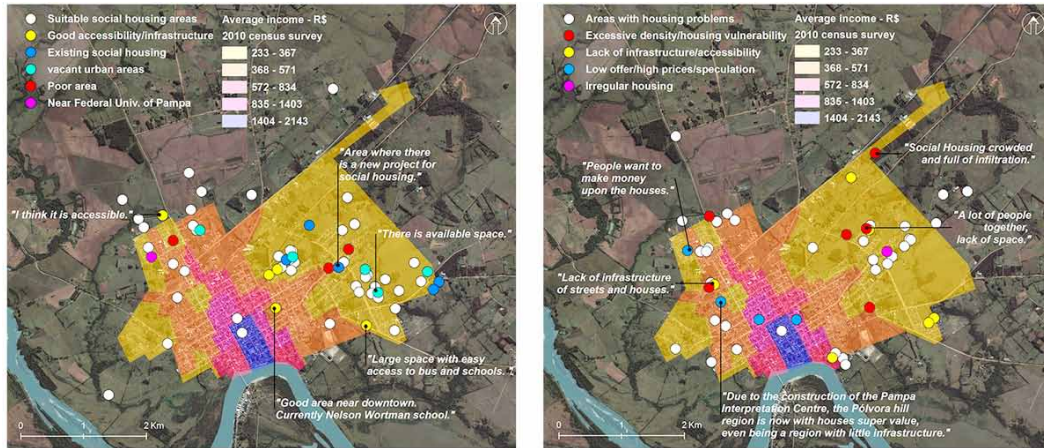


Figure 7. Suitable social housing areas (left) and existing housing problems (right) (Bugs, 2014)

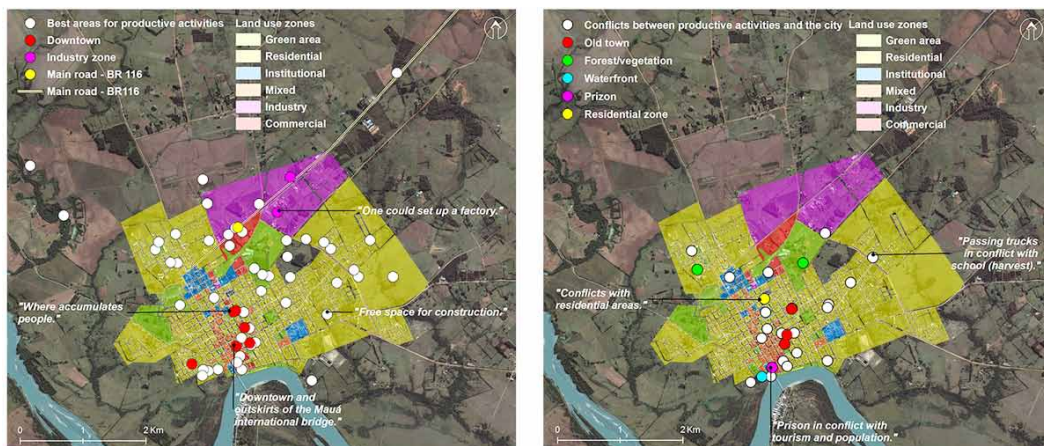


and housing vulnerability (6 of 19), lack of infrastructure and accessibility (6 of 19), and low offers, high prices, or speculation (4 of 19). One can see that the areas identified for social housing are concentrated on the city outskirts, in the same areas identified as currently having housing problems, which should be observed and solved in the case of choosing such areas for future social housing settlements.

Productive Activities

Figure 8 (left) shows the points marked as being the best areas for productive activities. In the comments, the most cited areas were downtown (6 of 12) and the industrial zone (2 of 12). Indeed, as the information layer overlap illustrates, most of the places marked by respondents correspond to downtown. Figure 8

Figure 8. Suitable areas for productive activities (left) and conflicts between productive activities and the city (right) (Bugs, 2014)



(right) shows the places marked as being areas where there are conflicts between productive activities and the city. In the comments, the most often cited areas of conflict were old town (3 of 8) and forest/vegetation (2 of 8). Respondents also mentioned conflicts in residential areas (1 of 8), truck traffic flow near the school area (1 of 8), and the prison site in the tourist area of the old town (1 of 8). One can see similarities in point locations between the two maps.

Free Trade Zone

Figure 9 (left) shows the points marked as being the best areas for the location of the free trade zone. In the comments, the most cited areas were downtown (3 of 13), the prison (3 of 13), along the main road (2 of 13), and next to the international bridge (2 of 13). One can see, by the information layers overlay, that the highest concentration of points is within the master plan's commercial zones, as well as in the areas closest to the free trade zones in Rio Branco, Uruguay. Figure 9 (right) shows the places marked by participants as being the worst areas for the free trade zone. In the comments, the most mentioned areas were far from downtown (10 of 6), the waterfront (2 of 10), and downtown itself (2 of 10). In general, the desire for the free trade zone to be near the bridge, similar to on the Uruguayan side, prevails.

Density

Figure 10 (left) shows the points marked as being adequate areas for new constructions, increasing density. In the comments, the most cited areas were the *Corredor das Tropas* (2 of 9) and areas with available space (2 of 9). These points coincide with the city's least dense zones. Figure 10 (right) shows the places marked as being unsuitable for new construction. The comments include downtown (28.5%, 2 of 7) and water resource preservation areas (28.5%, 2 of 7). In this case, the places coincide with the most dense and central areas. One can therefore affirm that participants are against new construction in the city's central areas, and there is a desire for city growth in the northern direction.

Figure 9. Best (left) and worst (right) areas for the free trade zone (Bugs, 2014)

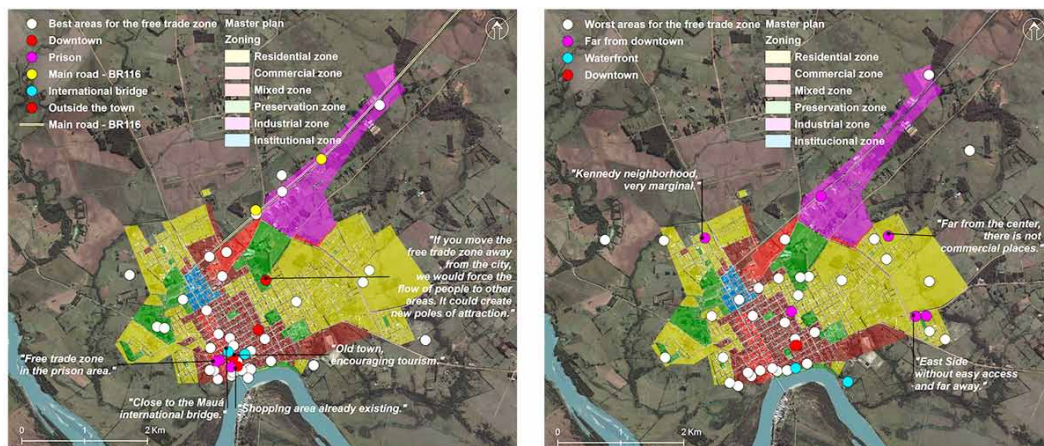


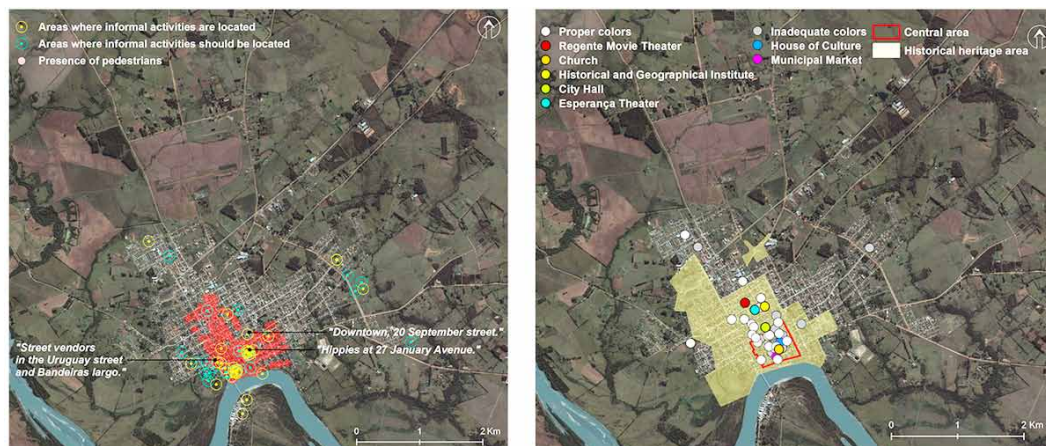
Figure 10. Adequate (left) and inadequate (right) places for new construction (Bugs, 2014)



Informal Activities

Figure 11 (left) shows the points marked as being areas where informal activities are located. In the comments, respondents mentioned Uruguay Street (2 of 9), 20 September Street (1 of 9), and 27 January Avenue (1 of 9). The points concentrate mainly downtown and in the bridge access area, which are coincidentally streets with a greater presence of pedestrians, according to the layer information overlay. In the same figure, there are also places marked as being areas where informal activities should be located, which generally are furthest from downtown and with lower presence of pedestrians, what is a contradiction.

Figure 11. Informal activities (left) and buildings with appropriate and inappropriate colors (right) (Bugs, 2014)



Chromatic Structures

Figure 11 (right) shows the points marked as having buildings with proper colors and points marked as having buildings with inadequate colors, in the respondents' perception. The buildings marked as having proper colors were Regente Movie Theater, the church, the Historical and Geographical Institute, City Hall, and Esperança Theater. On the other hand, the buildings cited as having inadequate color were the House of Culture and the Municipal Market. All had one point each.

Equipments and Infrastructure

Figure 12 (left) shows the places marked as being areas that need public equipments. Considering that the question had predefined options for multiple choice, the most cited equipments were sports areas (13 of 25), public squares (12 of 25), kindergartens (9 of 25), and health centers (8 of 25). One notices that there is greater demand in the peripheral areas, although the existing coverage is quite well distributed. Figure 12 (right) shows the points marked as being priority areas to receive infrastructure. Considering that the question had predefined options for multiple choice, the most cited infrastructures were lighting (20 of 22), sewage systems and rainwater collection (18 of 22), and road paving (17 of 22).

Aesthetics

Figure 13 (left) shows the lines drawn for streets perceived as being aesthetically beautiful and ugly in the respondents' opinion. In the comments, Uruguay Street and 27 January Avenue (Figure 14), both at downtown, where there are historic buildings, stand out positively, whereas suburban streets stand out negatively.

Figure 12. Areas that need public equipments (left) and infrastructure (right)
(Bugs, 2014)

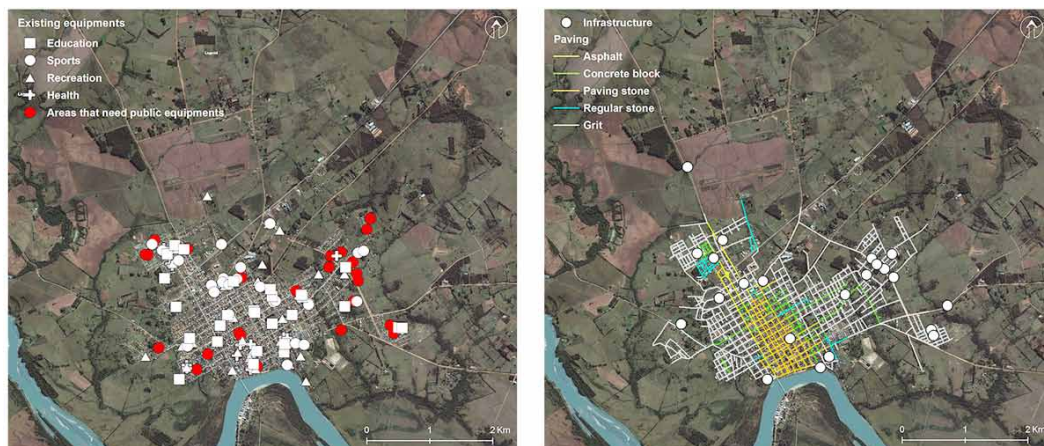


Figure 13. Beautiful (green) and ugly (red) streets (left) and better (blue) and worse (beige) streets (right) (Viana et al., 2013)

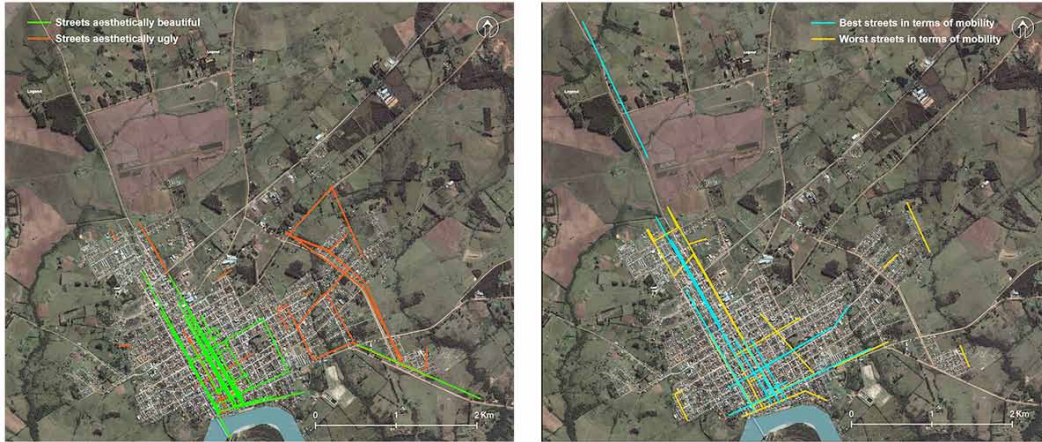


Figure 14. Uruguay Street (left) and 27 January Avenue (right) (PROEXT team)



(a)



(b)

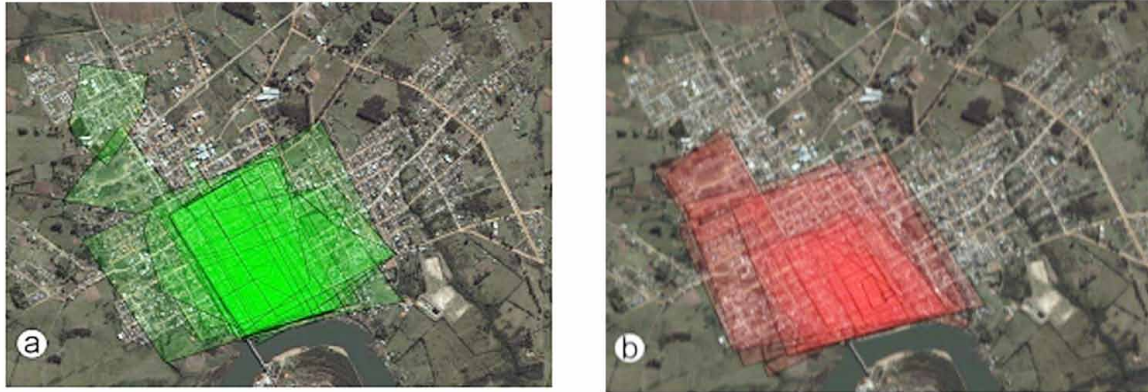
Mobility

Figure 13 (right) shows the lines drawn for streets considered the worst in terms of mobility. In this sense, there is the following comment: “All are really too bumpy and without conservation.” Besides the periphery streets, there are at least two in downtown considered to be the worst. The map also shows the lines drawn for the best streets. From the comments of the respondents, a widespread dissatisfaction with street conservation was evident.

Urban Zoning

Figure 15 (left) shows the overlapping polygons drawn to represent the downtown area. Figure 15 (right) shows the overlapping polygons drawn to represent the area that should be preserved for its architectural quality. There is a clear relationship between the area identified by respondents as being downtown and

*Figure 15. Downtown (left) and architectural quality (right)
(Viana et al., 2013)*

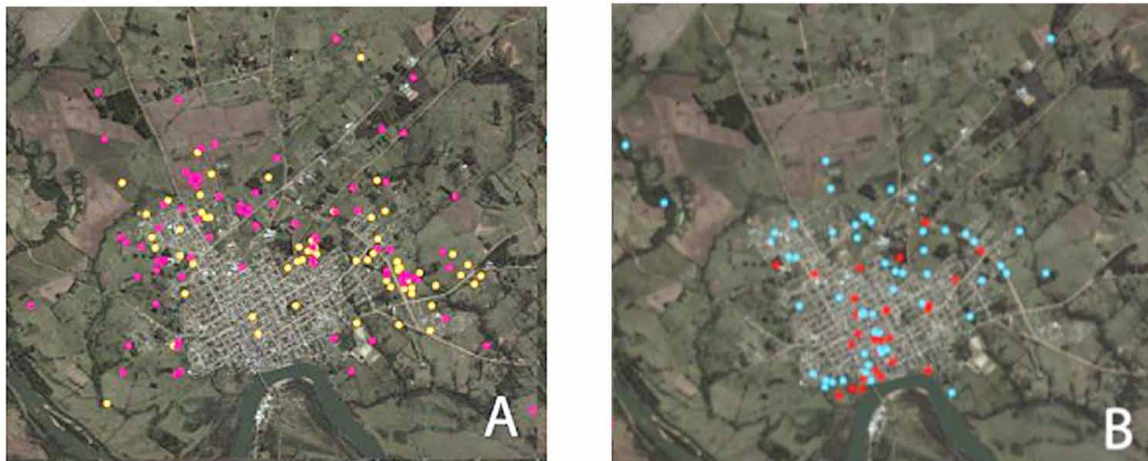


the area to be preserved for its architectural quality, with some variations of scale and place farther east or west of the central area.

It is also possible to perform information associations by overlapping different questions. For example, comparing the themes of urban development and social housing, it is clear that respondents consider the best areas for new residential construction to be ones around the city outskirts, idealizing urban growth mainly toward the north and northeast (Figure 16 left). Still, comparing the answers on productive activities and conflicts, there is a similarity between the best areas for productive activities and conflict areas (Figure 16 right).

In short, from the data collected with the PPGIS Jaguarão visual and exploratory analysis, one can highlight the respondents' opinions about the following:

*Figure 16. Urban growth (pink) and social housing (yellow) (left) and productive activities (blue) and conflict areas (red) (right)
(Viana et al., 2013)*



- Concern for the preservation and recovery of the Jaguarão river and wetland adjacent areas;
- Urban growth trends in the peripheral areas, especially in the northern and northeastern directions;
- The location of the future free trade zone around the access to the international bridge, similar to in the Uruguayan city of Rio Branco;
- Infrastructure provision in peripheral areas already occupied; and
- Downtown preservation.

Accordingly, through the contact established with the Jaguarão City Hall by the PROEXT team, it is expected that such results could guide future decisions related to urban space and could approximate local community concerns for the government, aiming to reduce spatial conflicts and drive urban growth in areas most suitable and desired. In principle, each urban intervention proposal should take into account the perception of the population. Thus, it is possible to incorporate the people's wishes already in the design of proposals, plans and/or future projects, facilitating the acceptance of the same by the public, and not only hold public hearing and/or public consultation approval or not proposals exclusively based on expert knowledge.

CONCLUSION

As for the proposed assumptions, PPGIS proved to be an effective method to provide useful, proper, and timely information that could be used to guide city planning with the knowledge of the local community. It was possible to identify positive and negative aspects of the urban space quickly and efficiently. From this specified knowledge of the local reality, inaccessible through official data sources, as discussed by Cinderby (1999), it was possible to obtain very specific guidelines for local community development (e.g., respondents want the free trade zone to be located around the international bridge).

This happens primarily because the data collected with PPGIS store the exact spatial locations of questions, that is, answers are connected to the spatial reference. The convenience of collecting data via an automated and georeferenced form optimizes and extends the capabilities of analysis, as highlighted by Kingston et al. (2000) and Poplin (2012). The 'soft' data is suitable to be manipulated in a GIS environment and processed along with other 'hard' information layers that make up an urban planning database. It confirms, therefore, that the 'soft data' (knowledge based on inhabitants' experiences), as advocated by Kahila and Kytä (2009), could form a fourth dimension in urban planning spatial databases.

The fact that public perception is represented in a spatial data layer facilitates its incorporation in the beginning phases of city planning and design. Public perception incorporation in the early stages facilitates public acceptance of proposals, preventing subsequent opposition to projects, as often occurs in cases in which the population has not been consulted in advance or officially informed, as Stern et al. (2009) and Rantanen and Kahila (2009) discuss.

Apart from the visualization and analysis of a variety of complex information together, the spatial distribution of public perception enables planners to transmit this information in a more accessible way to colleagues, decision makers, and the public in the form of maps, as highlighted by Van Herzele and Van Woerkum (2011). Thus, the maps generated from the data collected with PPGIS also have the potential to support further debate. Moreover, the usefulness of information collected with PPGIS is not restricted to the urban planning sector, as most of the information necessary for public policy formulation is inherently spatial (Sieber, 2006).

In addition, it is worth mentioning an important difference from the PPGIS method in comparison to more traditional methods of participation: the fact that there is knowledge construction in the map interaction process, the relevance of which is pointed out in the literature (see Innes and Booher, 2004; Lemmetty et al., 2005; Milakovich, 2010). By marking points on the interactive online map, people also discover things, become familiar with more abstract mechanisms of representation, and thus rebuild their perceptions of urban spaces. Therefore, one can affirm that participatory mapping, beyond representing space, also produces it, so providing a participatory mapping tool such as PPGIS can be considered a step toward citizen empowerment.

Regarding Arnstein's (1969) participation levels, which affirm that true participation occurs only when it reaches partnership, empowerment, or self-management, one can consider that there are technical and methodological conditions, through the use of tools like PPGIS, for a closer collaboration between society and public institutions. This would be considered an improvement on the usual practice of simply informing or consulting population about a finished project. If institutionalized, a tool like PPGIS would not necessarily give citizens direct control over decisions (given that in a representative democracy, the power of decision is legitimately given to elected representatives) but would allow valuable and inaccessible information through other participatory methods to quickly arrive to decision makers, promoting the extension of democracy, as suggested by Bobbio (2000).

In short, the results show that public perceptions collected by PPGIS form an extra information layer, which can be analyzed together with other information layers commonly used in urban planning. Thus, one can conclude that PPGIS have proved to be an effective method to learn about important aspects of the Jaguarão's local reality through the collection of the perceptions of a small group of inhabitants and a subsequent analysis of distributions and patterns of viewing.

LIMITATIONS AND SUGGESTIONS

A clear limitation of this study was the number of respondents. There was a lack of disclosure, a fact recognized by the PROEXT team. Once skirting this issue, the data quality could be enhanced, because the quality, according to Brown and Kytä (2014), is linked to the sufficiency of spatial data for meaningful analysis and the inclusion of all stakeholders. In this sense, it is understood that public perception collection through the use of PPGIS tools should be continued to make gains in quantity and quality of the collected data.

To increase respondents' representativeness in further PPGIS implementations, a suggestion is to apply more than one data collection method: one based on a stratified sample, by sending invitations and passwords for access to the public target, and another based on a voluntary wish to participate, through dissemination on social networks. It is also advisable to offer computers with Internet access in public places as a way to reduce the digital divide. Furthermore, it would be interesting to provide mobile device interfaces. Thus, it would be possible to answer questions at the same time that one is in the place in question.

The representativeness in online participatory processes is a recurring criticism, although the rate of PPGIS responses share the same challenges of other research with traditional methods (Brown and Kytä, 2014). The digital exclusion, for those not familiar with online maps, or without access to the Internet truly exist, but, on the other hand, the inexistence of online participation channels excludes part of society of participatory processes, especially the younger audience.

Stern et al. (2009) conduct a comparative study of online participation and attendance methods in Tel Aviv, and they found that participants in the Web differ from those of physical meetings. The public in the range of 30 to 40 years, with higher education, see the Internet as an additional opportunity for effective participation. The younger audience, in the range between 20 and 30 years with high school and entrepreneurs are those who participate only on the Internet. The older public, religious, used to-face contacts are those who participate only through traditional methods.

Mobilizing people to participate is a challenge in a fast-paced society. According to Fung (2006), although the opening of participatory processes to all those who want to participate have an obvious appeal in practice in almost all methods, those who choose to participate are often not representative of a large audience, regardless the method. Therefore, the use of various methods is the most appropriate. None is sufficient by itself. To expand participation, an ecology of methods, to support varied roles, based on different levels of experience, interests, motivations and access should be applied.

Another issue, which requires theoretical and practical deepening, is the geovisualization and interpretation of data collected with PPGIS. This question demands more attention from researchers and practitioners because although an information overlay exercise aiming to show relationships between variables and different interpretations of the issue at hand is key for urban planning, it cannot be produced easily (Kahila & Kytä, 2009). This study has observed that unlike with data commonly used in urban planning representation (physical-territorial data, socioeconomic data, and cadastral data), there are few studies specifically on how to represent and analyze the subjective and qualitative attributes mapped by the public, with the exception of Van Herzele and Van Woerkum (2008).

The map is the representation most often used to view and transmit geographic information, a graphical language that reflects abstractions from reality (Tversky, 2000). As such, enhancing this language is important for a better representation of the reality in question as well as to expand the communication capacity of the presented information. Therefore, techniques should be developed to improve the geovisualization and interpretation of geospatial information in PPGIS, making the results of analyses increasingly intelligible and useful for urban planning purposes.

Above all, a PPGIS research project that follows all stages of a participatory process is important. In this way, in addition to verifying whether PPGIS aid in the incorporation of public perception in urban planning in the form of a new information layer, one could verify whether and how this information could be assimilated in proposals, plans, and urban planning project formulation, given that so far there is little evidence that the PPGIS method has influenced “real life” decisions.

In practice, the expansion of public participation and the use of new tools such as PPSIG, requires the adoption of new working methods, as well as greater technical capacity to deal with both public opinion and with the new information flows in the digital era and the emerging smart cities. In Finland, some progress has been reported in this respect (Kahila, 2015). In Brazil, although in the discourse the government is open to public participation and new technologies, they are not yet fully prepared to do so in practice. While the potential to support decisions is widely recognized by managers, in practice the institutional barriers to effective public participation are many and remain unchanged despite technological advances and society changes in the recent years. Despite the recognition that the existing participation channels grew old and need urgent renovation (e.g. the participatory budget), government initiatives to provide alternative channels of participation are rare (Bugs, 2014).

Finally, the authors understand that a democratic and scientific approach as presented in this study represents the possibility of establishing a permanent system of collecting public perception about the

urban space, seen as essential for urban planning to become more collaborative and, consequently, enrich urban spaces.

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ENDNOTES

- ¹ For more information (Portuguese only), visit desenvolvimentourbanoemjaguarao.wordpress.com.
- ² As text comments were voluntary, there are differences in number from one theme to another.

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