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Designing for the Situated and Public Visualization of Urban Data

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ABSTRACT *This paper investigates the concept of urban visualization, the visual representation of an urban environment through its intrinsic or related data, where its display is also situated within that physical environment. It describes how the principles behind public and urban displays can be combined with those of social visualization and persuasive computing in order to create discursive as well as pictorial representations that provide a better and potentially actionable understanding of urban issues to its inhabitants. We introduce the role of several related research fields, and analyze a set of representative case studies, taken from current best practice, academic research studies, and an experimental design studio course to highlight the typical issues involved in conceptualizing and implementing an urban visualization. Lastly, the paper proposes a set of design constraints that typically characterize an urban visualization, in order to guide the future design and evaluation of useful applications within the field.*

KEYWORDS *Urban Computing; Public Display; Visualization; Urban Data; Persuasion; Design; Interaction Design; Physical Computing; Education*

Introduction

Humans are becoming an "urban" species, living in a large number of vast urban agglomerations. In fact, more than half the people on earth now live in cities. By 2050, it is expected that more than two-thirds of the world population will (United Nations, 2007). Yet cities around the world face various challenges of which the changing demands of demographics, mobility, energy consumption, quality of life, crime dynamics, economics, resource use, waste, culture production, and consumption, are just a few. While most citizens are becoming increasingly aware of the environmental, societal, and economic challenges that surround modern urban living, only few might comprehend the driving principles behind these problems, let alone reflect upon how these affect the reality of their own daily lives. Anticipating, understanding, and reflecting upon such urban problems is complex because of the sheer quantity and variety of interrelated parameters that influence these phenomena and their inherent dependence on the local context and sensitivities of a given location. No two cities in the world, or even two neighborhoods within the same city, are identical in the issues that residents

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face. Solving urban problems now requires taking into account the cultural, environmental, legal, or societal reality surrounding a specific place, in which the subjective experience and opinions of citizens are becoming as important as the physical manifestation of buildings and public services in the urban landscape. However, more localized decision-making typically requires higher resolution information gathering, in terms of quantitative measurements of the environment, but also in terms of collecting qualitative feedback from the very people who actually have to co-exist with, and within, these data. In order to gain a truer understanding of the influencing principles and tendencies behind growing cities, one should consider how to make stakeholders—i.e., citizens—better aware of the true nature of urban challenges. By involving the local population in understanding the driving principles behind current urban issues, more widely adopted and competent actions such as those induced by legislation and policies will stand a greater chance of improving the quality of life in cities, especially when part of the solution requires city inhabitants to change their ways of living.

One of the most pressing issues in cities is how to make them more environmentally sustainable. We claim that in order for urban inhabitants to become aware and act towards a more qualitative and sustainable urban neighborhood, a new way of communicating information will be required, involving both discursive as well as pictorial representations. Therefore, in this paper, we present the first exploratory steps in investigating the potential of representing "urban" data, or data that has a contextual relationship to the immediate environment, within the public, physical environment of the city as a potential solution for conveying actionable knowledge to local inhabitants. Moreover, the compelling communication of relevant, localized, and situated information might even change the perception of the physical environment in which the display is located.

Economic and cultural activities such as heavy industry and physical trade once helped define the local character of a city and its people through the various perceivable traces of their physical presence, such as the smoke from factory chimneys, the noise of local food markets, the dynamic flow of workers walking back from the factories or docks, or commuters leaving their neighborhoods in the morning. As many "western" economies shifted towards globalized service- and knowledge-based work, such urban activities have now become largely invisible and homogenous, leaving little physical trace of production. If the character of a place is linked to its production, how is local character and culture generated when production becomes invisible? Leaving aside the possibility of rediscovering forms of production with more discernible outputs, we believe this lack of character is perhaps best countered through tracking the continuous generation of "urban" data, which potentially contains the traces of productive activities and the many unique characteristics of our built environment. Therefore, through applying the appropriate representative means, the identity of place could still be distinguished and highlighted, making the identity of a place more tangible and relevant. To convey the implications of this changing nature of a city, a neighborhood, or a street, we thus propose to look for it through the lens of urban data, in the form of real-time digital traces of urban activities, as well as their qualitative impact on the local environment. By sharing this information through an expressive and socially shared medium such as a public display, we expect a sense of responsibility toward a place could be reinstated, which might even have the potential of changing local habits, attitudes, or behaviors. In the language of urban planning and urban design, this might even become a new form of "place-making."

The City as a Locale of Data about and for Its Inhabitants

Since the appearance of signage in the pre-industrial city to support spatial orientation and way-finding, valuable and situated information has been continuously displayed within the urban environment. By exploiting digital advances in screen and networking technology, such representations now have the potential to reveal information that is relevant, timely, and engaging for city inhabitants. Several movements and academic fields are currently converging around the idea of public and situated visualization in the urban context. The following paragraphs provide a short overview.

Open Data

"Open Data" is a philosophy that encourages the free and transparent distribution of data without restrictions of copyright, governmental oversight, or other mechanisms of control. The open-data phenomenon has been motivated by social movements that favor openness and transparency and the recent push towards encouraging technology-enhanced forms of participatory and public governing. While this ideology is well established in the context of scientific research and the Web2.0 phenomenon, the open-data phenomenon is only recent in terms of public governance and the built environment. The cities of San Francisco (*datasf.org*) and London (*data.london.gov.uk*) have been some of the first official urban authorities that have opened up large datasets on, and about, the built environment under the umbrella of facilitating transparent, accountable governing and participative citizenship. However, releasing such data to the public can hardly be considered sufficient, since to be useful, these data need to be presented in easily accessible and understandable ways. In recent years, various citizen initiatives worldwide have exploited the right to access and reuse public information as strategic tools for political influence and social action. The graphical representation of such data has led to significant changes in legislation, and has encouraged debate, changes in public opinion, and true citizen participation. The shared co-analysis of common data by participants forms a critical part of participatory action research and design (Bødker et al., 1988; Ehn, 1990). However, for a participative tool of this nature to be successful, it should be designed in a way that fits into the existing communicative ecology of its "users," here the city inhabitants. For example, locally relevant information might be best positioned in places that residents pass everyday. We believe that citizens should be encouraged to become more aware of current urban challenges through understanding the meaning of the hidden data of a city, when they are physically present within that city. Such an opportunistic way of presenting information that is essentially situated in a local environment should more easily overcome the obvious motivational and accessibility issues that are faced by traditional media communication formats, including mass mailings, online websites, or smart phone applications.

Social Visualization

Visualization, the graphical representation of complex information, has already been used as a feedback tool in an urban context, such as communicating urban interventions to the public, or for facilitating forms of participatory design and planning. However, most such visualizations have focused on realistic or experiential simulations of potential outcomes, such as for conveying the immediate implications of climate change (Nicholson-Cole, 2005). Realistic visualization, however, tends to emphasize the visual aspects of change, which may exacerbate people's existing tendency to relate reality solely to what they can "see" in their own neighborhood. Unfortunately, most urban challenges are abstract in nature and relate to a wide combination of interrelated quantitative and qualitative factors.

Non-realistic visualization, or by its more appropriate term, information visualization, has the power to convey "invisible" data, which has no direct counterpart in physical reality. Such abstract data typically requires some form of translation or mapping through an explicit visual metaphor to be perceived and, potentially to be understood. Visualization of abstract information for citizens in not particularly new: social and cultural theories of everyday life have always been interested in rendering the invisible visible, and exposing the mundane (Galloway, 2004). This interest has created the field of "social visualization," which tends to focus on enriching social, electronic communication by making its rich and salient qualities visible in easily accessible and understandable ways (Donath et al., 1999). More recent developments in this direction have shifted towards democratizing the power of visualization and making its advanced features accessible and usable for the public at large. Accordingly, social visualization offers non-experts the chance to increase their understanding of complex information by the power of collective and collaborative efforts (Viégas et al., 2007). Moreover, recent research efforts in this direction have demonstrated how lay people can be encouraged to create public visualizations for communicative and participative purposes, which by itself provokes sufficient motivation to even spur significant social activities (Danis et al., 2008; Gilbert and Karahalios, 2009; Heer et al., 2008). A few recent projects have demonstrated how social visualization has the ability to engage people in socially relevant topics, such as "PathFinder," which allows citizen scientists to collaboratively discuss and analyze the data they collect (Luther et al., 2009), and "The Village Buzz," an electronic notice board system that collects, shares, and visualizes user-generated multimedia content surrounding an existing high-density urban community development (Button, 2008). In essence, there thus exist some early empirical indications that publicly available visualizations can become appropriate communication media for sharing, discussing, and co-producing socially relevant data.

Urban Computing

Recent advances in sensing devices, wireless network connectivity, and display hardware have made the ultimate vision of ubiquitous computing finally possible, in which the "computer" as we know it becomes embedded in the physical objects and surfaces of everyday life (Greenfield and Shepard, 2007; Mitchell, 2004; Weiser, 1991). Similarly, "urban computing" is the research field that aims to apply this technological integration into urban settings and lifestyles, including streets, squares, pubs, shops, public transport, public buildings, and any other space in the semi-public realms of our cities (Foth, 2009; Kindberg et al., 2007). Driven by the increasing availability of urban data, together with the rising affordability of environmental sensors and the now ubiquitous use of mobile communication devices, urban computing aims to instrument the human experience of public space with digital information.

While most current research in urban computing focuses on improving the efficiency and productivity of activities in the city by the provision of locative services (e.g., mapping, way-finding), there is a recent understanding that contemporary urban life consists of a much wider range of emotions and experiences that needs to be addressed (Paulos and Beckmann, 2006; Townsend, 2010). For instance, the public visualization of "urban" data can play an important role in providing a better understanding of a place, as it has already been shown that, by combining existing data repositories with real-time sensor measurements and qualitative citizen feedback, valuable alternative views of the city can be created, potentially even in real-time (Calabrese et al., 2007). Such representations typically aim to reveal the salient patterns of urban living or make the impact of urban activities and their regulation understandable, such as to produce original insights into the nature of the contemporary city (Read and Pinilla, 2006), to digitally model and simulate the city (McGrath, 2008), or to investigate the spatio-temporal actions and opinions of city inhabitants (Vaccari et al., 2009). However, the resulting visual representations of the city still tend to be presented on dedicated media such as websites or smartphone applications, which are conceptually as well as physically separated from the actual environment from which the data originates, thereby turning the urban experience into a virtual one.

Urban Screens and Media Architecture

Today's "urban displays" are publicly accessible interfaces that allow passers-by to observe and potentially interact with functional information, ranging from bus schedules to dedicated tourism information (Fatah gen. Schieck, 2005). Such electronic displays are becoming increasingly ubiquitous in our urban fabric, as they now appear in squares and parks, around public transport platforms and, more recently, on-board public transport itself (Fatah gen. Schieck et al., 2008). However, the ideas behind the urban screen are slowly entering the realm of architectural design and construction: architectural facades, which traditionally either embodied the style of a specific time period (e.g., baroque, modernist), or represented the public function of the building (e.g., bank, church) have reached the technological stage in which they can be constructed independently from structural building constraints. As the typical rigid, weight-bearing facade is transformed into a flexible, almost weightless skin, an increasing number of buildings are becoming augmented with digital media. Technically, the nature of such displays can reach well beyond the traditional flat LED screen and its derivatives and even become integrated within the actual architectural or urban design. These treatments can range from subtly integrated interventions within the existing environment, by, for example, augmenting street furniture (Gaver, 2002); to "architectural" information surfaces that exploit state-of-the-art developments in thermochromatic panels (van der Maas et al., 2009); to dramatic mechanical and inhabitable structures that are able to dynamically change their shape (Oosterhuis and Biloria, 2008).

Content-wise, the obtrusive nature of its typical large, light-emitting panels is turning "media architecture" into an expressive language in its own right, influencing our experience of public space (Venturi et al., 1977). However, the majority of currently existing media architecture installations serve mainly commercial, artistic, or entertainment purposes. As research in this field has been mainly driven by technical challenges such as the development of fast-responding lighting systems or kinetically moving structures, its potential impact within the social and urban context is still often overlooked. Yet, through its explicit public dimension, media architecture has the ability to reach beyond its functional aspects, which it has in common with other human sciences. Through its particular way of expressing values, media architecture has the potential to stimulate and influence the urban experience without necessarily presuming that, in and of itself, it will promote social development. By combining the concept of the urban screen with the visualization of situated and contextual information, media architecture can grow beyond the broadcasting of artistic visual imagery, public announcements, or persuasive slogans, as it could facilitate bringing about a new understanding of complex local issues.

Persuasive Technology

While placing electronic displays in a semi-public space brings about new opportunities in social, community-driven communication and collaboration, it also raises important questions about the actual social and interactive behaviors occurring around a shared, public screen (e.g., O'Hara et al., 2003), including the potential to shape the opinions, attitudes, and behaviors of its audience. Because of its unique qualities, an urban visualization has the theoretical ability to persuade, because it embodies the three functional roles of *persuasion* (Fogg, 2003): through sensing technology, a display can act as a tool that increases the capability to capture a behavior (e.g., measuring residential energy consumption, bicycle use, etc.); through its visual imagery, it can function as a medium that provides useful information, such as behavioral statistics or cause-and-effect relationships; and through its networking ability, it can become a social actor, encouraging community-based feedback and social interaction.

However, the use of modern sensing and display technology for persuasive purposes in an urban context seems still relatively unexplored and is still limited to two very specific types: commercial advertising, such as the use of interactive visual effects to attract the viewer's attention (Mubin et al., 2009); and normative communication, including the widely adopted real-time roadside speed meters (e.g., "Speed limit: 50/Your current speed is: 65"). Displays designed to persuade seem to focus on providing some immediate reaction to local actions. As demonstrated in online media, social networks can form a useful construct to support behavioral change that involves group dynamics and the sharing and emulating of values. While online social networks tend to track and highlight the sharing of virtual values, similar concepts can be imagined in the physical world: an electronic car speed road sign would then not provide a numerical car speed readout, but, might, for example, provide a rewarding experience only when a cumulative shared goal has been reached or contrast your car speed as a distant commuter with that of local residents.

Towards the Public and Situated Visualization of Urban Data

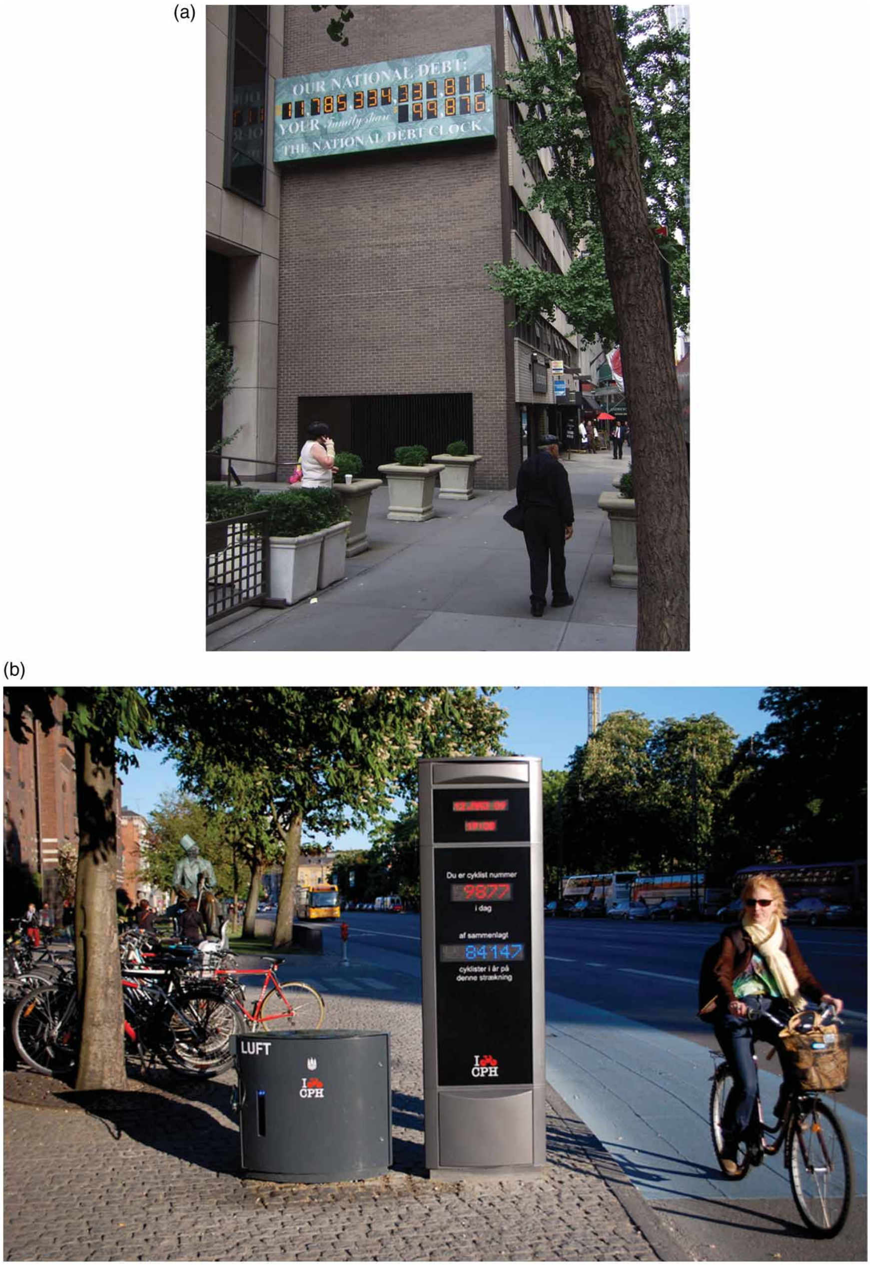
Visualizing complex information within everyday urban space is not a trivial task, as most city dwellers are well accustomed to ignore such public messaging, regardless of how large, brightly, or interactively the imagery might be presented. Accordingly, recent research on public displays and interfaces has been investigating the circumstances under which people actually "look" at such screens (as they tend not to) (Huang et al., 2009), how people can be enticed to interact with them (Brignull and Rogers, 2003), how the interest of people can be sustained beyond their initial excitement (Morrison and Salovaara, 2008), and how the interaction with public screens tends to change over time (Jurmu et al., 2009). While such studies reveal the driving influential factors behind the performance of such displays, few working prototypes have been designed that demonstrate the novel conceptual possibilities of visualizing information within an urban context. Therefore, the following sections provide a short overview of the current state of public visualization, seen through the lenses of three different practices: private and governmental conceptual proposals and real-world implementations, research through design studies, and educational design courses.

Best Practice: Current Concepts and Implementations of Urban Visualization

The U.S. Debt Clock (Wikipedia, 2011) located in New York is a continuously updated large-size dot-matrix display that presents an estimation of the current gross national debt in the United States, in addition to each family's share of that debt. (See Figure 1a.) Next to the immense size of the numerical values, the animated effect of the continuously increasing number is in itself a quite disconcerting way of alerting people of the relative speed of public debt acquisition. While its relevancy goes well beyond the immediate city neighborhood, its location in Manhattan, the financial center of the United States, is still quite apt. The display conveys a sense of urgency on a personal level, as the elusive total debt number is averaged to that of the level of a single, average family.

The Cykelbarometer (Mikael, 2009) in Copenhagen also displays numerical data, though with a more localized relevance, as it broadcasts the daily and yearly total number of bicyclists that rode past. (See Figure 1b.) Located at one of the main entrances of the city, the number counts upwards immediately after a bicycle is sensed, providing a sense of participation and belonging. The goal of this display is to inform as well as persuade onlookers to commute more with a bike: in fact, it is not about being the first, but about being the cyclist with the number 500,000, who will receive a free bike from the local city administration.

CityWall (Morrison et al., 2008), in contrast, is a more elaborate screen in the form of a multi-touch surface installed in the center of Helsinki, giving access to past and present events that took place in the city. Due to its advanced interactive features, it has been reported that passers-by seemed rather interested in the novelty and the playfulness of the interface, rather than the actual content.



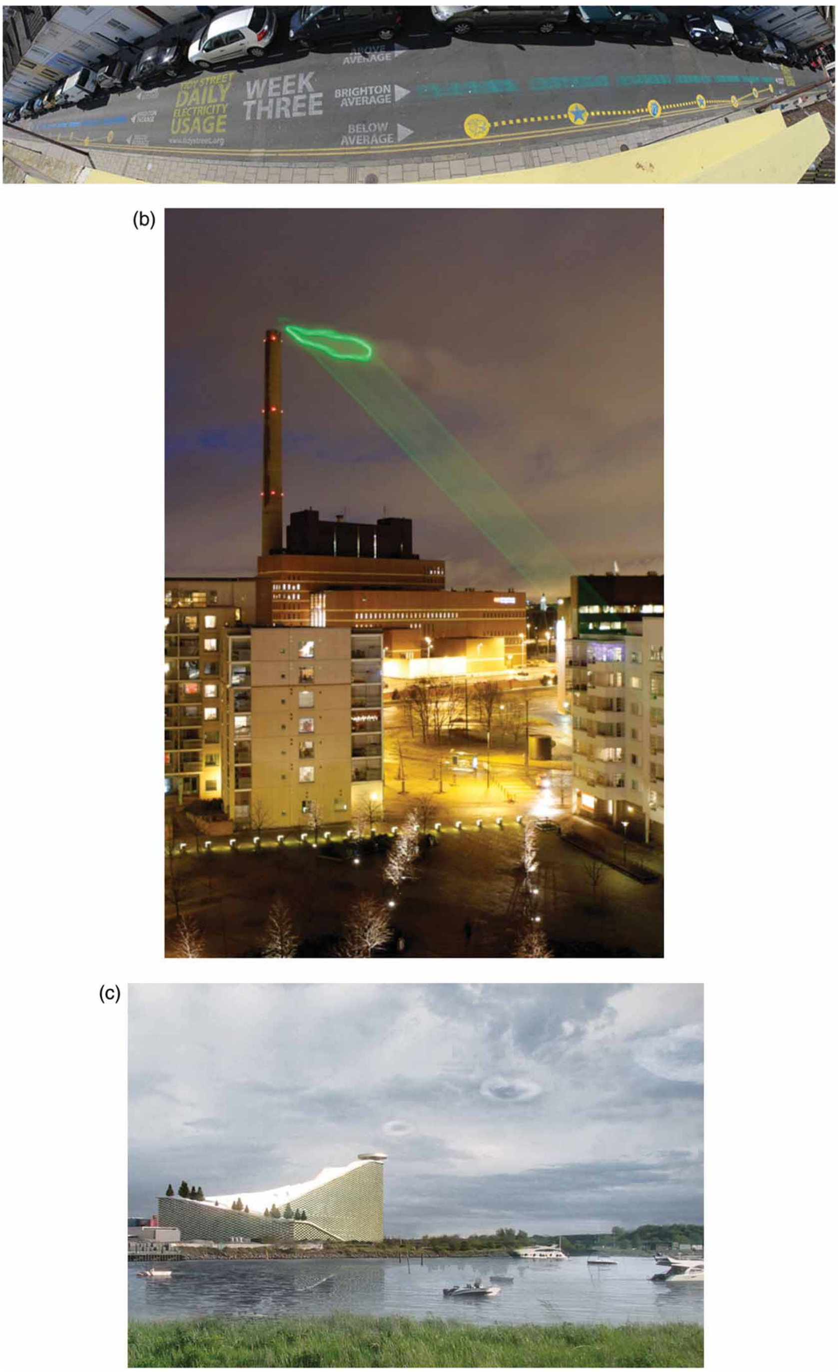
Figures 1a and 1b: Examples of existing forms of urban visualization using digital display technology (a) U.S. Debt Clock in New York City and (b) Cykelbarometer in Copenhagen
Sources: (a) Wikipedia, 2011, (b) Mikael, 2009

Analogue versions of public visualization displays exist as well, as shown in Figures 2a, b, and c. The Tidy Street project (Bird and Rogers, 2011) consists of a huge historical line graph, painted with chalk on a common road, which reveals the historical electricity usage of the street's inhabitants, contrasted to the average values of other UK regions. Although the street display is temporary, it

(a)

(b)

(c)



Figures 2a, 2b, and 2c: Figures 2a, 2b, and 2c are examples of urban visualization using "analogue" display technology. (a) Tidy Street, Brighton (U.K.), (b) "Pollstream-Nuage Vert," Helsinki, and (c) "Big Vortex," Copenhagen

Sources: (a) Bird et al., 2011, (b) HeHe, 2008, and (c) realities united, 2011.

aims to motivate the local community to participate in lowering energy consumption and to support the display's continued upkeep. (See Figure 2a.)

Ars Electronica 2008 laureate "Pollstream—Nuage Vert" (HeHe, 2008) is a city-scale visualization of sorts, which transformed a cloud emanating from an electricity plant chimney into a meaningful projection surface: the more the local inhabitants saved energy, the larger the surface area that lit up through the use of a powerful (though low-energy) laser light. (See Figure 2b.)

"Big Vortex" (realities united, 2011) is a soon to-be-built built waste-to-energy plant that will represent a quarter ton of processed CO_2 emissions by regularly emitting a visible gas cloud in the shape of a circular smoke ring (or toroidal vortex shape). (See Figure 2c.)

In the project "Melbourne Smart City" (Arup, 2011), the global engineering firm Arup proposed several urban visualization concepts within the strategic framing of a smart city vision for the city of Melbourne. The proposed ideas ranged from relatively "traditional" large LED screens that reveal real-time, street-wide water and electricity use, to more futuristic public art installations such as a floating LED cloud that conveys patterns of urban activity as a form of shared artistic experience. (See Figures 3a and 3b.)

These examples, some already implemented, some still in a conceptual phase, demonstrate the relative infancy of urban visualization and the relatively limited data complexity (in terms of size and dimensionality) that has been exposed to inhabitants until now. It seems that the ideal vision of the so-called "real-time city" (Foth, 2009; Ishida, 2002), in which continuous urban data flows are commonplace and freely available, has yet to arrive. Instead, the data sources used in currently existing urban visualizations are still relatively "simple" in terms of their technical implementation, though nevertheless still hard to come by.

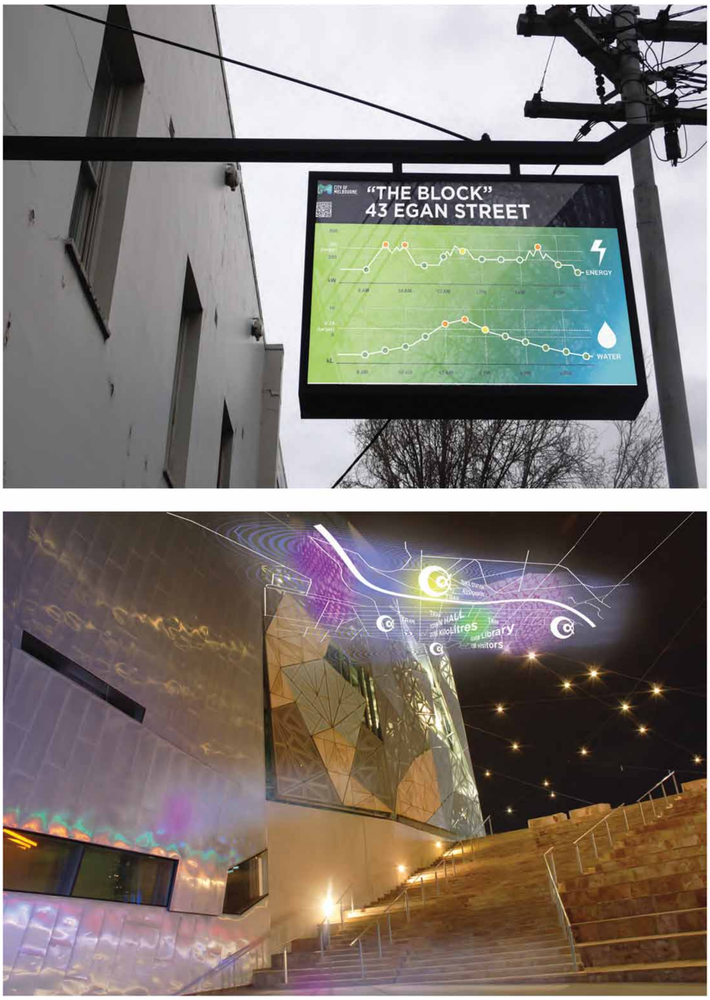
Academic Research: Investigating the Urban Visualization of Private Data

In our recent in-the-wild design study (Vande Moere et al., 2011), we installed a series of custom public displays on house facades in Sydney (Australia) to investigate the effectiveness of explicitly externalizing household energy consumption—information that is normally kept well hidden and private. During the 10-week study, the daily electricity usage statistics of several households were displayed on their respective houses, so that any positive or negative change in their habits became immediately comparable to those of other nearby households. As shown in Figures 4a and 4b, the study comprised a set of custom-designed chalkboards, which were hung on the facades of five different houses and on which the information was updated by hand by the researchers, once per day. The boards included several visualization techniques in order to investigate the specific factors that influence the effective perception of the information by inhabitants and passers-by.

We hypothesized that the public exposure of household energy statistics would have a positive and possibly a sustained effect on electricity use by triggering feelings of healthy competition, social comparison, or social pressure (Abrahamse et al., 2005). However, the effectiveness of the "public" context, in terms of explicitly comparing the behavior of multiple persons with each other, is still relatively contested: while some past studies showed immediate and positive effects (Brandon and Lewis, 1999, Egan, 1999), others have revealed how people

(a)

(b)



Figures 3a and 3b: Figures 3a and 3b are conceptual ideas of urban visualization for Melbourne's Smart City Program. (a) Civic Smart Meter: here streets and blocks broadcast their resource data (e.g., energy and water use), (b) The Net, a layered net of LED lights hangs over a Federation Square "laneway," displaying civic data in real time.
Sources: (a) and (b) Arup, 2011

tend to be concerned about the apparent validity of the comparison groups (Roberts et al., 2004). Public and open comparison of behavioral data has some important drawbacks: while bad-performing participants might change their behavior positively when being confronted with those of others, good-performing participants tend to do the opposite, as they feel much less encouraged when noticing their already positive behavior, and feel no immediate objection to move towards the "average" (Brandon et al., 1999).

The design through research methodology demonstrated some of the real-world challenges of urban visualization and the effectiveness of *in-situ* evaluation studies to measure the effectiveness of conceptually convincing ideas. For instance, while many real-time visualization techniques can be easily imagined, it becomes a challenge to design a publicly noticeable display that is cheap, sus-

(a)

(b)

Figures 4a and 4b: Design research on urban visualization. Comparative public visualizations of energy use statistics in Sydney (Australia). The boards showed a set of visualization techniques, including daily performances facts, a neighborhood ranking, an historical energy use graph, and a visual long-term reward in terms of a pictorial bar.
Source: (a) and (b) Vande Moere et al., 2011

tainable in itself, easily updatable, acceptable by local residents, but also resistant to the urban environment, including "real" aspects as materials, safety, vandalism, weather, council approval, privacy issues, and so on. This project also revealed some non-obvious motivational issues when urban data is put in the public realm, most of which are related to how people interpret "change" instead of absolute use values, our inept method of rewarding sustained behavior, and an inability to connect the insights derived from the visualizations into direct, positive actions. Accordingly, we believe more research is required on how to best present complex data in a public context, in terms of being understood as well as facilitating actionable sense-making.

Education: Design Studio Experimentation

"Urban Sensing" was a postgraduate design studio course organized within the Master of Interaction Design and Electronics Arts (M.IDEA) program at the University of Sydney (Vande Moere and Hill, 2009). Students were challenged to design and build a working prototype of an urban visualization within the existing context of a real-world urban location nearby the university campus.

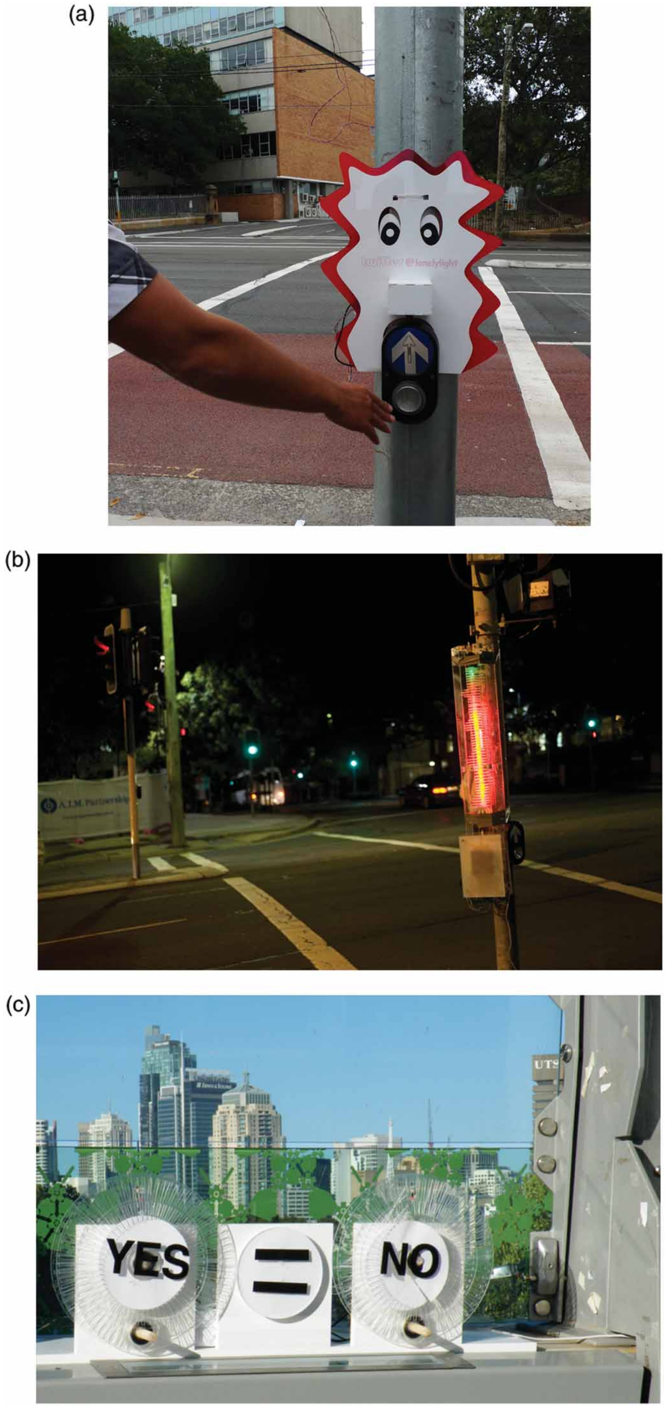
The student design ideas were fine-tuned through iterative evaluation cycles of successive low- and high-fidelity prototypes on the intended site location, and by personally observing and reflecting on the reactions and opinions of actual passers-by. The course demonstrated the practical, real-world issues of designing a public and situated visualization, and the difficulties in inventing case scenarios that are both meaningful and feasible. The issues we encountered ranged from accessing interesting urban datasets that were actually publicly available (those that were, were taken offline after discovering our use), to confronting police officers worried about security who took down all our wireless sensor devices that were mounted on the site.

The following three student works, as shown in Figure 6, demonstrate the conceptual richness of "visualizing" urban data in more creative and artistic ways, unrestrained from council policies or pragmatic functional considerations. The "Lonely Traffic Light," designed by Silje Johansen, turned the inanimate and anonymous nature of an ubiquitous urban construct, a traffic light, upside down: an existing traffic light was electronically augmented to enable it to "interact" with its users, even appearing to express emotional responses to waiting pedestrians. Small proximity sensors recorded the requests from pedestrians to cross the street (i.e., when users pressed the green light request button), and the exact states of the traffic lights themselves (i.e., captured by a light sensor attached to the green pedestrian light). A rudimentary form of artificially intelligent personality was implemented through a rule-based behavior algorithm. The output mechanism of the traffic light consisted of text-to-speech messages that were emitted by a hidden, miniature speaker, as well as two real-time Twitter streams, one of which revealed the actual binary state of the traffic light, and the other its emotional response about the current situation (e.g., lonely, bored, stressed, all based on the sequence and time stamp of past events). The successful implementation proved the potential for augmenting existing urban furniture instead of developing dedicated displays, in particular as a way to exploit its explicit physical context (e.g., the combination of a waiting area, busy road, and a normally lifeless object) to encourage passers-by to contemplate the new situation. In the context of interaction design, a typical traffic light could be considered a relatively ideal "interaction interface," as it is equipped with one of the largest and most intuitive forms of input mechanisms (i.e., a big, shiny, metal button), while it is relatively easy to capture the full attention of multiple (and often bored) "users" during a relatively long period of time (at least when the light is red). Here, this interaction opportunity was exploited to orally inform pedestrians about their expected waiting time, which was calculated from past averaged measurements and the time since the light was last seen as green and to tell traffic-related jokes, whose duration depended on the expected waiting time. Occasionally, the traffic light communicated apparent emotional responses, such as utter irritation when people indifferently pressed the button numerous times. (See Figure 5a.)

Student Steven Lukman augmented a common traffic light with a more functional goal in mind: to inform the people approaching the traffic light as well as already waiting pedestrians about the expected waiting time for a green light. He implemented two wirelessly connected and "futuristic-looking" contraptions such that the approach and the waiting were transformed into a rather spectacular data-gathering experience. This was conjured via the sequential blinking of a series of red/green colored LED lights that denoted the passing of time, and a calmly rotating spiral of Perspex discs (causing a visual effect much like the rotating "waiting" icons found in operating system interfaces or on the façade of typical old barber-shops), all encapsulated in a protected transparent, vertical contraption. The two output devices were distanced from each other such that the interface attempted to convey the imminent change in traffic light state to oncoming pedestrians some distance away from the actual lights. While more subtle than the Lonely Traffic Light project, and undoubtedly more complex than necessary to communicate a waiting time, this project turned the everyday task of waiting into an aesthetic experience that rapidly became a popular conversation topic with passing strangers. (See Figure 5b.)

The "Urban Polling Device" by Jack Zhao, provides an alternative way to conduct and visualize opinion polls on public streets. The device enables pedestrians an opportunity to vote "for" or "against" a certain issue through physical interaction with a tangible device that registers their vote and displays the overall trend. Passers-by can rotate one of the two discs, which itself is accompanied by a tactile "click" and a sound to acknowledge the recording action. The middle circle contains a "=" sign, of which the separate physical parts can be electronically animated to resemble "> ," "=," or "<," depending on the acquired voting statistics. While the device has no direct interventions for obvious misuses like multiple voting, it still opens up the question of agency and cooperative behavior in urban contexts. It also hints at an urban experience that is increasingly "metered" through the use of sensors and other input devices, as well as a culture of participation and public consultation. As such, the polling device prototype suggests a myriad of potential applications in terms of gauging the responses of citizens via an opportunistic, everyday device in the street, and providing the results back to the people at large. (See Figure 5c.)

As an exploratory and research-led teaching course, we realize that much of the perceived innovation of the proposed student projects rests with the relative novelty of embedding alternative information displays in a real-world, urban context. Both the physical and social (Williams and Dourish, 2006) context plays a surprisingly important role in designing for urban computing: what might work fine in our design studio environment or a controlled laboratory environment, was often perceived completely differently on-site. The typical goal-oriented character of an urban dweller, together with the continuous stimulation of our human senses by attention-grabbing advertising, noisy traffic, the harsh



Figures 5a, 5b, and 5c: Figures 5a, 5b, and 5c are examples of design education in urban visualization. They picture experimental but working prototypes. (a) “Lonely Traffic Light” by Silje Johansen, (b) “Waiting Light” by Steve Lukman, and (c) “Urban Polling device” by Jack Zhao

Australian sun, and an amalgam of smells, makes the urban environment a particularly difficult context to design for. Accordingly, our students often did not anticipate how the vast majority of city dwellers would overlook their carefully crafted displays. Design subtlety and whimsy often had to be replaced with straightforward, large, robust, and "in-the-face" approaches that are difficult to ignore.

Conducting research through design outside of the typical lab environment proved to be a huge development challenge. As opposed to design interventions that tend to exist solely on paper or in virtual worlds, which all can be upgraded, downgraded, or tweaked at any time, the integration of "physical computing" in an urban context is often unforgivable in trivial issues, ranging from last-minute changes, however small, to common physical occurrences like a missing power source, an over-curious passer-by, a severe rain storm, or a nervous security guard. Although many user-friendly and open-source software frameworks have provided creative designers with the opportunity to step into technological territories normally reserved for the expert or hobby enthusiast, the key to successfully develop a convincing urban computing prototype seems to be mostly driven by thorough self-determination and the continuous urge to be critical of one's own work. Even the slightest technical error, caused by inexperience, trial-and-error, or just the occasional accident, will typically make an experiment fail completely, often even to a point where repair is too complex, time-consuming, or costly.

It should come as no surprise that some of the student projects, not shown here, failed to convince in terms of producing plausible, useful, and elegant urban design solutions that would genuinely enhance or contextualize the urban experience. As teachers, we could frequently employ a "so what?" test in order to gauge many of the proposed ideas, i.e. "So what if your system tells us the road is busy or the bus is just arriving; we can see that for ourselves..." or "So what if your data show a correlation between bike use and rainy weather; that is to be expected." Obvious reasons for the lack of surprising applications of urban visualization might include the high complexity of the design challenge itself, particularly for a largely foreign student cohort who had no personal experience with the urban context as a living environment, and, therefore, could not react to it as a design framework. In addition, the issue of providing city occupants with a "feedback" mechanism that transcended that of standard LED lights or LCD displays was often experienced as a creatively insurmountable bottleneck. The simplicity of programming blinking lights and housing them by rudimentary cabling was often too persuasive. In short, while these problems may reflect particularly on our students and/or us as teachers, still we get the sense that urban visualization itself could be caught between highly functional, almost banal components of urban infrastructure on the one hand, and highly abstract or oblique design interventions, interactive or not, on the other. This phenomenon may be a reflection of the open-endedness of the still emerging field at this time, partly because few of the more interesting datasets are actually available, or that the range of possible interventions into the urban experience is vast and effectively unconstrained.

Characteristics of an Urban Visualization

How is a situated urban visualization different from an interactive advertising billboard, an electronic council announcement screen, or a public, roadside speed meter? Based on the related fields and the examples that were discussed in the previous sections, we believe that its determinant design characteristics are threefold:

Situated

Here, "situated" means that the visualization is embedded in a real-world, physical environment.

Contextual. The visualization takes into account the unique characteristics of its physical location, in terms of both its explicit and implied meaning. An urban visualization often receives its meaning from the metaphorical context of its location, making detailed explanations unnecessary: a display attached to a house facade reflects the behavior of the resident household, smoke coming out of chimney represents pollution, a light-emitting artifact attached to a traffic light depicts a waiting time, and so on.

Local. The information shown has a direct and immediate relationship to the local context. This often means the data is sensed, measured, or acquired within the physical environment immediately surrounding the display, or has been modeled into values that reflect the particular circumstances of the people, buildings, or activities within the local environment. The data sets can originate from authorities, such as governmental or advocacy organizations (e.g., open data in the form of crime statistics, school inspection reports, etc.); crowd-sourced repositories containing geo-located information (e.g., Flickr, FourSquare), or from private or socially-motivated initiatives that employ their own environmental sensing devices (e.g., mobile phones, pollution sensors).

Social. The visualization reflects on issues that are closely relevant to the social-cultural reality in its vicinity. The local population can easily identify with the issues raised through the data, ensuring a level of usefulness and utility that goes beyond a specific time or a specific individual user (persona).

Informative

The data are different from those on posters and electronic announcement billboards in several ways.

Feedback. The visualization forms a direct feedback loop between the city, its inhabitants and their actions. Urban data are created by city inhabitants and are different from services, time schedules, or other urban phenomena that exist independent of urban inhabitants. An urban visualization thus forms a factual mirror, which must dynamically change according to the activities of inhabitants to be truly believable (and potentially persuasive). Equally, it may be that the form of the visualization itself needs to change over time, in order to retain the interest of its regular passers-by.

Insightful. The visualization allows onlookers to create meaningful insights beyond the retrieval of facts (e.g., events, routes, time schedules). Insights are discoveries of understanding that are essentially: complex, deep, qualitative, unexpected, and relevant (North, 2006). Allowing insights to be discovered has two main challenges: on one hand, the visualization should represent data phenomena (e.g., trends, outliers, clusters, contrasts) that are sufficiently complex and meaningful, on the other, the visual representation should be sufficiently intuitive to be comprehensible.

Consistent. The visualization in itself does not negate the meaning it conveys. Accordingly, a display showing CO_2 emissions needs to be sustainable in itself.

Functional

The following aspects assure the effective functioning of an urban visualization, which corresponds largely to the requirements of common urban displays, including advertisements, road signs, council announcement boards, graffiti, and so on.

Medium. The visualization is designed as to reach a sufficiently large audience, irrespective of their technical expertise, cultural background, or motivation. (Note: it may be that multi-sensory additions can successfully augment visualization.)

Participative. The visualization provides an experience that is shared by a community of people, potentially encouraging participative and collaborative action and the sharing of common norms and values.

Opportunistic. The visualization does not impede other urban activities. It is perceivable in the periphery of human attention, allowing viewers a free choice to dedicate their full focus or attention. Accordingly, its information is not of vital or crucial nature.

Aesthetic. The visualization is adapted to the urban fabric. It takes into account the constructive and aesthetic constraints of its surrounding environment and blends in visually as well as physically, and thus ensures a sustained acceptance by the local population.

Trustworthy. As with any public intervention, the visualization shows information in an objective, fair, and trustworthy way that accurately reflects the actual situation. For instance, the sources of the data that were used are clearly mentioned and are publicly accessible.

Persuasive. Similar to advertising and announcement boards, an urban visualization calls for some sort of reflection, change, or action. Designing and building public displays requires considerable time and effort, which typically must be compared to some sort of future benefits that offsets these investments. Or, put another way, the "value" of providing information to citizens centers around the general expectation that a more informed population tends to be more satisfied, more involved, leading to more informed discussion and participation in public discourse.

Following these design characteristics, it should be clear that an urban visualization should be ideally designed considering, or with the active participation of, the actual local citizens, in order to create a feeling of ownership and personal involvement. Notably, none of the characteristics defines the need for digital display technology: although the feedback loop between citizens and their activities through their digital data traces requires some form of dynamic updating, its display does not necessarily need to be updated in real-time. Similarly, the topic of interactivity has not been directly discussed. Interactivity should be considered more widely than the standard keyboards, multi-touch surfaces, or smart phone applications in order to guarantee a wide public acceptance, by those "users" who typically are not conscious of current technological advances.

Conclusion

The increasing presence of electronic communication devices in urban settings has the unfortunate tendency to reduce sociality. As a result, the role of the built environment as an ideal place for producing and sharing information is diminishing through the increasing interaction between computers and people. At the same time, developments in sensing, networking, and displaying technology have led to new forms of media that can be located in public spaces. Placing information media within an urban environment has the advantage of keeping the spatial experience tangible and multimodal, as opposed to the relatively one-sided and passive interactions with smart phones, even those that use augmented reality features.

The visualization of complex urban data on screens seems a promising technique to shape the next generation of public feedback. In particular, the insights from social visualization form a valuable platform on which applications can be built that have the ability to motivate and engage people in topics relating to urban challenges. Many current examples of urban visualization exist (see also Townsend, 2010), though most seem limited to the presentation of single data attributes (e.g., more or less energy consumption, total number of commuting bicyclists), that miss the opportunity to present more dimensional and rich relationships that form the very basis of the city as a complex system. What such visualizations should look like, where they should be located, and what issues they would be ideally suited to tackle, however, are some of the open questions that require further investigation, ideally through research on design methods. Viable examples might include feedback loops on living quality and satisfaction versus historical city investments, the impact of urban and legislative decision making, the effect of official traffic interventions on real-time traffic performance, the role of local inhabitants in creating a unique sense of place, and so on. Two of the fundamental prerequisites that would make this possible in the future are the opening of more public data with social interest and local relevancy, and an attitude change in tolerating citizen interventions in the public realm. Accordingly, not all of these applications can be commissioned, managed, or owned by city governments—indeed, an opportunity exists for non-governmental bodies to publish and manage such civic data, upon which others could build novel applications for, and hopefully with the full support of, local citizens. Once a sufficient amount of socially relevant and situated data become freely available, and local authorities have become more tolerant to bottom-up interventions within its, and our, public space, new kinds of urban applications will emerge that might even be able to compete with those that exist on today's mobile devices.

In the information society, it has become obvious that our cities are valuable and relevant sources of data that require rigorous aggregation, analysis, and public dissemination. This paper aimed to assess the still untapped opportunities of media channels other than the traditional computer and smartphone displays. We also argued that by returning urban data to citizens, those data can be used to create meaningful insights about the city and to become a form of knowledge that can lead to civic action.

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