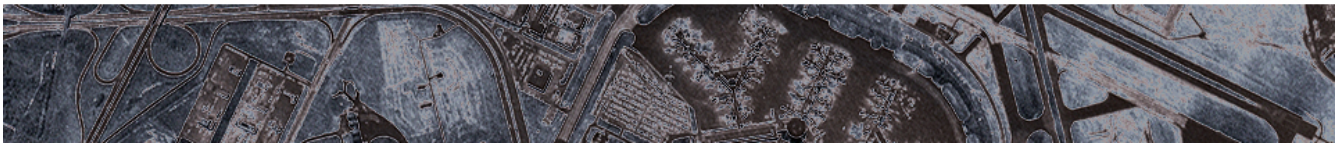
The Fibreculture Journal
DIGITAL MEDIA + NETWORKS + TRANSDISCIPLINARY CRITIQUE
issn: 1449-1443



FCJ-214 Visions of Urban Informatics: From Proximate Futures to Data-Driven Urbanism

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Abstract: Urban informatics is positioned to offer unique insights into complex urban processes through use of big data and pervasive computing. This paper examines the rise of urban informatics as a field of expert urban knowledge, with a focus on the particular visions and epistemologies of the city embedded within the field. By exploring its emergence over the past decade, and reflecting on connections with previous eras of urban computing, the article explores questions about the kind of city that is occupied, resolved and reformed by urban informatics and associated lab-style data sciences.

doi:10.15307/fcj.29.214.2017

Introduction

Urban informatics, the nascent field that took as its subject the urban contexts of increasingly connected, smartphone-enabled citizens, is ten years old. Armed with tools of digital experimentation, data science, and design, equipped to decipher and decode complex urban environments, the field is increasingly positioned as a vital contributor to the contemporary urban sciences. The proliferation of distributed computing throughout our cities presents seemingly unlimited opportunities to explore and interrogate the workings of the city using novel methods of information retrieval, analysis and visualisation.

Reflecting this opportunity, investment in urban informatics research capability is growing. In 2012, three significant research institutes focused on establishing city-focused data sciences capabilities were created in New York alone, [1] joining existing groups such as Queensland University of Technology's Urban Informatics Research Lab and the MIT SENSEable City Lab in promoting the applications of urban science and informatics to improving cities. As well as these urban informatics labs, there are now hundreds of initiatives, platforms, specialist interest groups and government investment programs that are actively pursuing novel data-driven approaches to understanding the fabric of urban spaces, with a view to generating better outcomes for our cities. Predictive analytics, machine-learning tools, open APIs (application programming interfaces), crowd-sourcing platforms, distributed sensors associated with the Internet of Things, programmable screens and novel sensing apps are but a small selection of tools

developed with the intention of improving the functional performance of cities and with it, everyday conditions of urban liveability. These tools allow urban informatics to claim the city as an 'urban laboratory' (Karvonen and Heur, 2014), a territory utilised for the purposes of practical experimentation, prototyping new solutions, and designing opportunities for new ways of living in the city.

While a relatively new entrant to the field, the Center for Urban Science and Progress (CUSP) has bold ambitions to become the world's leading authority in urban informatics. Led by New York University and NYUPoly, CUSP promotes a new model of public-private education that seeks to create real-world applications of urban data to help solve a wide range of urban challenges. With an annual operating budget of $70m, its partners include the City University of New York, Carnegie Mellon University, University of Toronto, University of Warwick, Indian Institute of Technology Bombay and technology leaders IBM, Microsoft and Cisco. Like other urban informatics laboratories CUSP maintains a commitment not only to research and education, but also to 'real demonstrations of new tools and new solutions' (CUSP, 2013: 9). For CUSP the city of New York is claimed as both 'laboratory and classroom'. Its website describes its approach to urban informatics as one that 'observes, analyzes, and models cities to optimise outcomes, prototype new solutions, formalize new tools and processes' thus developing new expertise and experts in the field (CUSP, n.d). [2] The use of computer science in urban governance and decision-making is by no means completely novel (Bettencourt, 2013; Lee, 1973; Townsend, 2013), nor is it confined explicitly to the field of urban informatics. The more recent rise of 'big data' and smart cities as powerful urban innovation agendas (boyd and Crawford, 2012; Kitchen, 2011), along with high profile investments into new entities like CUSP, has helped to propel the field forward. Ten years after the first urban informatics lab was created at QUT in 2006, the same year that geographers gathered in the UK to discuss the promises and perils of urban informatics, we can use the span of a decade to reflect on the challenges and opportunities of how we 'compute the city'.

As a uniquely hybrid discipline, variously defined but necessarily spanning an interest in cities on the one hand, and information science on the other, today's growing interest in the potentialities of urban informatics continues to surface old tensions that have continually haunted attempts to quantify and measure complicated, dense and unruly urban spaces. As is well known, previous eras of urban planning confronted major tensions in the measurement of cities, leading to a loss of confidence in the assertion of 'general' or 'comprehensive' theories of the city, reliant on quantitative models alone (Lee, 1973; Townsend, 2009, 2013; Batty, 2013: 272). This recognition of failure in the ability to construct useful scientific models of the city stemmed from a realisation that computer models were not capable of grappling with the daunting complexity of cities (Lee, 1973; Batty, 2013: 272).

And yet today, a potent combination – involving steady advances in computing modelling, simulation and predictive analytics relating to the workings of the city and its subsectors (transportation and land-use planning, for example), and massive amounts of machine-readable data associated with rapid personal device uptake and an emergent Internet of Things – means we need again to confront the possibilities of a 'science of cities' (Batty, 2013; Townsend, 2015; Bettencourt, 2013), one that is now more confident in its contributions to the 'real world' contexts of urban design, planning and governance. Does this confidence, this upswing of interest in and support for urban informatics, mean we have overcome historical limits to the objectification of cities? Or, put another way, what responsibilities does urban informatics bear, in this age of pervasive data and digital disruption, when it attempts to construct a domain of urban expertise that spans both the information sciences and the urban condition? Such questions are not easy to answer,

but this should not stop us from asking them.

This paper reflects on the rise of this field over the past decade, and traces the territories it has claimed, along with the kinds of urban spaces rendered through its disciplinary associations. The intention is to advance a better understanding of how the city has been 'computed' in recent years by those attuned to the increasingly central role of digital computing in urban contexts. This shifts the focus somewhat, away from questions about how 'informatics', big data, or even 'smart technologies' might be *applied* to urban problems, by looking in more detail at how 'the urban' is constructed as a space to be occupied, resolved and reformed by informatics and data science laboratories. Where information science produces its own particular map of the territory (we ought to call it a data visualisation), here we retrieve a sometimes-unfashionable idea that how we *imagine* the city can also help shape what we hope we can gain from our devices.

It is worth noting that this paper is not so much a detailed assessment of the possibilities of urban science today, something Townsend has been investigating in recent years (2015), though it does attempt to capture the particular claims of urban informatics as an emergent discipline. While urban informatics is a young discipline, the shifts and divergences that have taken place within the field over the past decade deserve critical attention. By considering urban informatics in this way, it is hoped that the lessons from previous debates concerning the place of computing in the city might play a part in the way we might consider the present moment; opening up critical territories relating to how the spaces of the urban are governed, experienced, shaped, lived, marketed and imagined into being.

Modern urbanism is ever-inflected by a philosophical conception of the city based on an idealised Athenian polis and its notion of the agora. 'The city' as Jameson (2005: 5) reminds us, presents itself as the 'fundamental form of the utopian image'. It is this conception that continually nourishes us to think of the modern city according to a model of the antique city, the ideal city and the rational city (Lefebvre, 1996: 98). While there is a great deal of attention towards, and investment in, new processing tools for sensing and visualising urban complexity, we need to re-assess the extent to which contemporary attempts at digitally-driven urban engagement may be subject to the same vulnerabilities as have plagued historical modes of urban utopianism. How do we counter the endemic utopian tendencies of the urban with a rational assessment of what our contemporary computational capacities might offer the difficult work of necessary urban reform? And likewise, how do we counter the stubborn reliance on *technics* as solutions to complex socio-spatial challenges? As urban informatics matures as a discipline over the coming years, such questions won't necessarily find easy answers, but they will surely require some attention.

What is Urban Informatics?

> The increasing ubiquity of digital technology, internet services and social media in our everyday lives allows for a seamless transitioning between the visible and the invisible infrastructure of cities: road systems, building complexes, information and communication technology, and people networks create a buzzing environment that is alive and exciting. (Foth, Choi and Satchell, 2011: 1)

Let's begin with some definitions. Howard Rheingold is thought to have christened the field, writing in a 2003 article entitled 'Cities, Swarms, Cell Phones: The Birth of Urban Informatics' in which he reviews the work of 'urban informatician' Anthony Townsend in straddling the co-evolution of cities and personal media

(Rheingold, 2003; Foth, 2009a; McCullough, 2013: 196). [3] An Urban Informatics Colloquium held in December 2006 at the University of Durham, UK, explored contemporary intersections between urban theory and social informatics, but offered no single definition (see Ellison, Burrows and Parker 2007: 785). Williams, Robles and Dourish then defined urban informatics through its placement at the 'intersection of computer science, design, urban studies, and new media art' (2009: 2). McCullough has more recently ventured a useful definition of urban informatics as a field that seeks to 'collect, share, embed, and interpret urban infrastructural and environmental data' (2013: 196). For Foth, Choi and Satchell (2011), 'driven by curiosity, initiative and interdisciplinary exchange' urban informatics is understood as:

> 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 (2011:4).

These authors, associated with the first urban informatics lab of its kind established at the Queensland University of Technology in 2006, locate their focus as the 'qualities of place, technology, and people in urban environments' (see for example Foth, Choi and Satchell, 2011: 2). Inter-disciplinarity is key, then, and so, too, are points of intersection between the physical, or 'hard' infrastructures of the city, and the 'soft' informational spaces of ubiquitous network computing; sometimes also described as the emergent 'hybrid' spaces of augmented, mobile media (Goggin, 2006; de Souza e Silva, 2006), post-desktop computing, wearable devices, and the Internet of Things (ITU, 2005).

But while the possibilities of the digitally-instrumented city have attracted attention from a wide variety of disciplines, urban informatics asserts itself not only as an *object* of study, but also a mode or ethic of *practice*. Thus, to Anthony Townsend (2009: xxiii), urban informatics constitutes 'the collection, classification, storage, retrieval, and dissemination of recorded knowledge' both *in* and *of* a city. As an *object* of study, urban informatics articulates the space of the city as a complex informational system; as a *practice* it advances the new capabilities and uses of distributed, ubiquitous technologies in order to better understand and indeed improve the experience and performance of the spaces and places of the city. The work undertaken within urban informatics laboratories has remained highly practice-oriented, with technology trials and app development and design used primarily as tools for research into the impacts or uses of digital technologies in urban contexts.

Where does UI come from?

Urban informatics itself is a relatively new field of practice, however it draws from a range of historical influencers and disciplinary alignments, spanning the rise of informatics, ubiquitous computing, human-computer interaction and participatory media. Informatics emerged in recent years as a highly applied science, generally defined by the gathering, use, retrieval, and visualization of information. As Verhoeff has noted, informatics is always *both* information and its processing (2013: 140). [4] Studies of the disciplinary divergences of the field (for example, Rosenbloom, 2013) have traced close alignment to the field of biology (bio-informatics), with more recent applications focusing on the applications of big data to newer domains, including neuro-informatics, energy informatics and business informatics. Across many of these fields, informatics is known to introduce an ethos of practical experimentation and utility.

Informatics also predates the focus on data science applications. During the early 2000s, it was more

closely associated with information and communication technologies (ICTs), and attempts to understand the practical contexts of computer usage. This gave rise to particular fields of community and social informatics. For example, Guerstein advanced the term 'community informatics' to challenge the device-centric nature of much digital divide literature in the early 2000s, in order to firmly situate 'the design and implementation of ICT systems in their community and social context' (2003). This helped shift the emphasis within studies of Internet uptake towards the everyday contexts of 'effective use' of ICTs, rather than simply counting who was connected and who was not. Kling (2000: 246) championed the role of 'social informatics' as the 'interdisciplinary study of the design, uses and consequences of information technologies that takes into account their interaction with institutional and cultural contexts.' As a field, it 'defined a topic and set of fundamental questions, rather than a family of methods' (Kling 2000: 246). Early research into social informatics, undertaken as early as the 1970s and 1980s, focused on organisations as major sites for studies of the impacts of computerisation on work processes and organisational planning (see Kling, 2000).

To Foth, who has championed the need for a specifically *urban* informatics, and helped to delineate the new field through his edited collection, the *Handbook of Research into Urban Informatics* (2009a), the term 'informatics' has been closely associated with studies of information processing and, via social informatics, the social contexts of ICTs. It offered a useful term to be co-opted as a way to likewise shift focus away from the physical hardware associated with urban computing and digital urban infrastructure, and towards the 'softer aspects of information exchange, communication and interaction, social networks, and human knowledge' (2009: xxix). Of course, information processing in cities is not unique to the era of digital disruption, or indeed to the rise of urban informatics, but has long been claimed an 'age-old function of cities' (Mumford, 1961; Mitchell, 1996; Graham and Marvin, 2001). As Townsend wrote in the same collection: 'Taking a long view of urban informatics, the simultaneous urbanization and global economic integration we are currently experiencing can best be seen as *a refinement of the city as a system for information processing*.' (2009, xxiii; my emphasis).

Nevertheless, there is something particular about the contemporary trajectory of information processing in the city that sets itself apart from previous eras. For Townsend:

> [I]t seems that after 50 years of incubating digital information technologies on the desktop, we are now at the point where they are to become inextricably woven into the everyday social and economic life of dwellers in every city on the planet… Like Frankenstein's monster, the physical fabric of cities is waking up and becoming aware of itself (2009: xxiii-xxiv).

A sense of the physical fabric of cities 'waking up and becoming aware of itself' was for many years somewhat speculative, and drew on anticipatory projections by architectural futurists such as William J. Mitchell. In *City of Bits* (1996), Mitchell noticed the way that more and more of the instruments of human interaction were becoming miniaturised, dematerialised and cut loose from fixed locations. It was a shift, he believed, as significant a reform to the urban fabric as the construction of Haussmann's nineteenth century Parisian boulevards (3). But unlike Haussmann's grid, the 'invisible city' of the twenty-first century would, Mitchell argued, be shaped more by the a-spatial logic of networked data which would 'turn classical categories inside out, and [would] reconstruct the discourse in which architects have engaged from classical times until now' (1996: 24). This 'city of bits' would not be rooted to any definite spot on the surface of the earth, and would be shaped by connectivity and bandwidth constraints, rather than land

values or physical accessibility. In this model, places would be 'constructed virtually by software instead of physically from stones and timbers, and they will be connected by logical linkages rather than by doors, passageways, and streets' (1996: 24). For Mitchell, the spatial syntax of networked information disclosed a new spatiality: the widespread digitisation of material urban spaces underscored the need for 'imagining and creating digitally mediated environments for the kinds of lives we will want to lead and the sorts of communities we want to have' (1996: 24).

The speculative quest for appropriate metaphors to describe the radical *strangeness* of these 'cities of bits' has been widespread, and certainly not limited to the work of urban informaticians: from the 'real-time city' (Kloekl and Ratti, 2011), the 'sentient city' (Crang and Graham, 2007), 'the internet of things' (ITU, 2005), programmable cities (Kitchin, 2011), pervasive urban computing (Kindberg, Chalmers and Paulos, 2007) to the notion of 'everyware', what Greenfield (2006: 1) calls a 'vision of processing power so distributed through the environment that computers effectively disappear', referencing the ideas of Mark Weiser (discussed shortly). For those interested in the place of computing in the city, it became clear that the sense of cyberian apartness that once distinguished the speculative interest in virtual 'cyber cities' of the 1990s, when the Internet was still just something you 'went to', was disappearing. Rapid innovations in computer processing power, including miniaturization and advances in micro-processing, would, during the 2000s, ultimately undermine any sense of material transcendence. Rather than McLuhan's abandoned cities, left as 'cultural ghosts for tourists' (1969: 12), ubiquitous access to the Internet would become an increasingly *infrastructural* condition through which many interactions *within* the urban world would take place. As Mitchell (1999) may have put it: 'Urban life, Jim, but not as we knew it'.

Urban informatics emerged to respond to this increasingly mobile, pervasive nature of computing, ready to claim as its subject the everyday urban conditions of ubiquitous computing. Where Sassen's global cities analysis (2001) referred to the structural tendency for informational processes to *agglomerate* in global cities, the focus for urban informatics shifted to the material spaces of information *diffusion*. For Dan Hill, in a seminal 2008 essay 'The Street as Platform', it was necessarily through the scale of a 'typical high street', that we should best understand the informational spaces of urban life. Sketching out a series of everyday episodes and localised interactions occurring in a nameless street, Hill paid close attention to the kinds of invisible data these interactions were producing, at once 'collective and individual, aggregated and discrete, open and closed' (Hill 2008: para 4).

Thinking about streets as 'urban interfaces' reflects ideas from the field of Human-Computer Interaction (HCI), particularly where it has pushed for new interaction experiences that encourage people to use their computers in novel ways (see Foth et al., 2014). HCI researchers and designers, working within and beyond the realms of the computer sciences, have actively pursued new interaction design opportunities that pay close attention to the social and psychological contexts of computing (see Dourish, 2001: 61; also Suchman, 1987: 10). Arguing for a 'more profound basis for the relative sociability of computer-based artifacts', HCI proponents such as Suchman (1987) have advanced the notion of the computer as a social object. Drawing from the observational techniques and practices of HCI, urban informatics has in turn advanced the need for new interface design possibilities, taking on the scales of streets, masterplans, mobile devices, sensor and Bluetooth technologies and everyday wayfinding as necessarily integrated fields of design practice.

For urban informatics, the everyday urban spaces of mobile computing have remained a key focus. This has helped distinguish it from other cognate fields of study, such as locative or mobile media (Goggin,

2006; de Souza e Silva, 2006), or computer modelling or simulation (Batty, 2013). As Foth put it, this embedding of informational technologies within everyday spaces allows for the 'more human elements of communication and information exchange' to come into focus, not simply 'specific technologies or devices' (Foth, 2009a: 2), but their contexts of use.

This links the field strongly with the preoccupations of ubiquitous computing, or 'ubi-comp', a term coined by computer scientist Mark Weiser, who led a team at Xerox Palo Alto Research Centre (PARC) in the late 1980s. Weiser's influential 1991 paper published in *Scientific American* called 'The Computer for the 21st Century' outlined a new 'ubiquitous' or 'pervasive' model for personal computing that would place the computer in the foreground of our attention. Describing the potentials of 'experimental embodied virtuality' (Weiser, 1991: 81) that would 'take into account the natural human environment and allow the computers themselves to vanish into the background' (89), Weiser anticipated a shift away from solitary, immersive computing interactions and their 'centripedal forces', to much more socially-integrated contexts (89). This orientation towards social context within ubi-comp provided a conceptual scaffold for urban informatics, and set up conditions for active interdisciplinary exchange. As Weiser advised in a keynote lecture given in 1994: 'Start from arts and humanities: philosophy, phenomenology, anthropology, psychology, postmodernism, sociology of science, feminist criticism, your own experience' (slide 10, in Bell and Dourish, 2011: 14). In other words, place ubi-comp within a broader disciplinary conversation with science and technology studies, socio-cultural anthropology, and media and cultural studies (see Bell and Dourish, 2011: 45). To 'get computing out of the way', is not only to make computing physically invisible but rather to let it play a role in agendas that originate elsewhere.

Taking on this stance, practitioners of urban informatics are often working as urban activists seeking to reshape the urban environment. Honing in on street-level data provided a means to reform the very fabric of the 'urban interface' itself (Hill, 2008). For Townsend, the smartphone is claimed as a platform 'for reinventing cities from the bottom up' (2013: xiv). It is the potential for widespread citizen-centric participation in the reform of the city that has been pursued as one of the greatest benefits of mobile, ubiquitous access. As compared to the stance of more 'objective' urban science centres such as work originating out of UCL's Centre for Advanced Spatial Analysis (CASA), urban informatics has tended to pursue an urban reform agenda through a highly anticipatory set of claims about both its object of study – the city as a space for information processing, the spaces of the city filled with intelligent sensor devices – and the relative potentials of pervasive, networked computing to reshape the city towards more open, participatory models of urban governance and decision making. In other words, the city of urban informatics has been conceived as an agent of change, its potential for transformation (good or bad) closely linked to the rate and scale of instrumentation.

This particular anticipatory orientation is worth exploring in more detail. When assessing the research outcomes and practices associated with urban informatics over recent years, it seems clear that many lab-style interventions and prototypes have served as provisional markers towards *potential*, preferred futures. Technology trials and research-led prototypes have tended to reinforce a fairly positive view of ubiquitous computing as enabling more open platforms for participatory engagement in planning and urban decision making (Paay et al., 2007; Wallin et al., 2010). They chart potential futures, but as research trials, experiments or prototypes, they also work outside of the mainstream institutions of traditional urban governance, with relatively confined and controlled measures of success. This can mean the wider complexity of achieving broader systemic change, where it might entail critically influencing wider

institutional regimes of decision-making, governance and investment, can figure as the messy work best left to others.

Urban App-tivism: Remake the City with Your Phone

For much of its short history, urban informatics has championed the idea of the mobile user as an interventionist agent of change in the city. The Urban Informatics Research Lab at QUT established in 2006, [5] has done much to advance urban informatics which it describes as a discipline that uses 'instruments for live surgery' to not only render the invisible visible, but to create a 'buzzing environment that is alive and exciting' (Foth, 2009b: par 2). One forum held in Australia in 2010 introduced the mobile phone user as instigating disruptive behaviours capable of activating new or hitherto repressed currents of citizen engagement. Here, a city 'decentred by the new fluidities of mobile communications' was envisioned as one operating more efficiently, thus 'encouraging greater opportunities for interaction' (Satchell, 2009: par 1). In this study, the city's capacity to become 'decentred' reflects the mobility of device users' communications patterns.

The SENSEable City Lab, a well-known research initiative located at the Massachusetts Institute of Technology (MIT), has for more than ten years championed the tools of urban informatics through lab-style interventions and technology experiments. The Lab founder, Carlo Ratti, has advocated the tools of urban informatics as capable of radically transforming the way we describe and understand cities. The Lab 'studies and anticipates these changes from a critical point of view', producing applications and graphic representations of 'real-time cities' whose dynamic data flows help illuminate complex urban behaviours (MIT, n.d.). These data visualizations, well known to many, have generated a visual palette through which to capture today's highly-informationalised urban spaces as porous, networked and globalised. One of its first projects, *New York Talk Exchange* (2008), illustrated the global exchange of information in real-time by visualizing volumes of long distance telephone and IP (Internet Protocol) data flowing between New York and other cities around the world. As the project site noted: 'In an information age, telecommunications such as the Internet and the telephone bind people across space by eviscerating the constraints of distance' (MIT, 2008a). Another early SENSEable City Lab project, *Real-time Copenhagen* (MIT, 2008b), [6] used mobile devices to track people's movements through the city, displaying the pulse of Copenhagen's *Kulturnatten* (culture night) as it unfolded in real-time. This project built on earlier work such as *Real-time Rome* (2006), [7] which similarly used mobile phones and GPS devices to collect the movement patterns of people and transportation systems and their spatial and social use of streets and neighbourhoods. *SmartBiking*, another Lab project implemented in Copenhagen during 2009, utilises a self-organizing smart-tag system to allow the city's residents to exchange basic information and share their relative positioning with each other (MIT, 2009).

Many of the SENSEable City Lab's software applications have depended on willing participants sharing their personal mobile use data in aggregate form. In return, users are encouraged to think of themselves as actively 'participating' in the production of new urban interfaces: interfaces not of physical surfaces, but of informational use. The work of the Lab has been overt in its attempt to not monitor mobile users through a kind of sinister, top-down urban surveillance, but instead encourage mobile users to think of themselves as actively contributing to the production of novel ways to 'picture' or 'make visible' their environments. The appeal of crowd-sourced data obtained through mobile devices and apps has been in the way it reveals what Hill (2009) refers to as the proximate 'soft infrastructures' of the city, the rich patterns of everyday

urban behaviours, and the complex, multi-layered networks which take in the various different socio-cultural, material and environmental natures of urban space.

Through these enhanced powers of observation, allowed through illuminations of networked GPS devices and sensors, practitioners have claimed the means to reveal that which was previously unseen. In this view of the urban scene, real-time cities are at once revealed and celebrated as objects of data flow and analysis, allowing for new affordances for urban change. As Carlo Ratti once pointed out, in discussion with Hill (see 2009: par. 11):

> [W]e're hardly going to change or destroy all these existing buildings and spaces anytime soon – urban form just doesn't change that quickly – but *the profound changes in the way cities feel and function may be in this internet-enabled informational layer*. (my emphasis)

While not always explicitly aligned to urban informatics, the claim that new digital platforms such as smartphones can be used to transform the way our cities are understood from a 'traditional' urban planning perspective has been quite widespread. Research undertaken by the Institute for a Broadband Enabled Society (IBES) at the University of Melbourne for example, claimed great potential associated with the shift from cyberspace to pervasive computing, in opening up 'new possibilities of social interaction in public spaces' while at the same time presenting 'new possibilities of appropriation of public spaces which challenge the status quo of urban planning theory' (IBES, 2009: par. 2). Where the Euclidian framing of geographic space was subjected to sustained critique for its simplistic organisation of complex spatiality, the use of ubiquitous computing has been widely celebrated as the 'vector of a new geography' (Holmes 2006). For Madera (2010, in Bettencourt, 2013: 10):

> What's different about the information age that has been ushered in by personal computers, mobile phones and the Internet is its ability to reshape the social organization of cities and empower everyday citizens with the knowledge and tools to actively participate in the policy, planning and management of cities.

In this way, ubiquitous technologies and sensors have been championed as a new kind of 'architecture of participation' (Williams, Roubles and Dourish, 2009: 4); a burgeoning field of 'read/write urbanism' (Greenfield and Shepard, 2007) in which traditional urban, social structures and governance methods could be radically reconstituted according to the 'techno-social assemblages' associated with the participatory cultures of networked mobile use. This orientation echoes architecture's fascination with cybernetics in the 1960s and 1970s, as exemplified within the work of studios such as Archizoom, Archigram and Superstudio (see Scott, 2007). These studios drew from the logic of cybernetic feedback loops to identify ways for citizens to play an active role in shaping the space they inhabit using 'non-plan' material architecture, proposing material interventions that were open, extendable and adaptable to changing patterns of use and activity.

Urban informatics has continued this activist focus on 'citizen centric' applications of urban technology. In recent years, opportunities for increased participation in city-making through digital technologies have been most closely associated with the rise of Web 2.0 technologies (Foth, 2011; Rheingold, 2002) – more so than traditional modes of urban participation in the form of, for example, citizen council juries or participatory urban planning forums. Where interest turned to the rise of user-led content creation, digital

social interaction using Web 2.0 applications was, for a time, widely seen to offer enhanced interactive and collaborative capabilities, not only within digital spaces (Munster and Murphie, 2009; Ang and Pothen, 2009) but for participatory democracy more broadly. New media advocates such as Pierre Lévy (2001), Henry Jenkins (2009), and Howard Rheingold (2002) helped to pioneer an appreciation towards the way networked experiences of online interaction might create new kinds of social co-ordination and 'collective intelligence' via exponentially increasing network links. In these contexts, once-passive consumers of media are transformed into active, content creating producers – once called 'produsers' (Bruns, 2007). Rheingold's *Smart Mobs* (2002) captured the radical potentialities posed by the ability of groups of people connected using mobile technology to meet each other at a particular location and time, generating spontaneous public protests or expressions of co-ordinated play. 'Participatory culture' as advanced by Jenkins (2009: 3) likewise described the radical cultural shift taking place, as online users adopted new practices of media consumption and communication that contrast dramatically with older notions of passive media spectatorship.

Aligned to this work, urban informatics championed the potentials of participatory media to reclaim 'traditional' urban spaces, and to reconstitute city contexts with the more exciting spaces of digital connectivity. Where non-networked spaces may have been subjected to 'traditional', 'top down' planning, digital spaces of urban interaction could, through the use of mobile devices, become much more 'buzzing and exciting'.

The Smart City: From Participatory Agora to Corporate Nightmare?

This hopeful orientation towards the potential for smartphone-connected citizens to reshape the city in more open, democratically-motivated ways appears to have waned in recent years. Once enthusiastic proponents of urban informatics have cautioned against the co-optation of platform technologies by corporate power, particularly in relation to the smart city. In 2013, Anthony Townsend, Adam Greenfield and Dan Hill each published their own 'manifestos' in which they spelt out their growing disillusionment towards the tech-enabled smart city: Greenfield's *Against the Smart City* (Greenfield and Kim, 2013) was written 'to bury the smart city not to praise it'; Dan Hill's essay 'On the Smart City: Or, a Manifesto For Smart Citizens Instead' (2013) implored readers to beware of technology control systems dressed up as smart, sustainable urbanism, and called for a renewed focus on 'smart citizens', via the computational capacities of social media and smartphones. For Townsend, much of what has driven the innovative capabilities of digital platforms – openness, interoperability and innovation – is at risk of being left out of a data-driven urban innovation agenda, as technology vendors sell proprietary platforms that lock in their customers and expose them to inappropriate risk.

Referring to Jane Jacobs' framing of city as a complex web of interactions, Townsend warned that the framing of smart cities as proprietary technology platforms risks denuding them of the vitality and innovation that will be needed to serve their cities, and their citizens, well. Suspicious of the 'seductive pitch' being crafted by the giants of the technology industry who see massive financial opportunities to be gained in the funding of smart infrastructure services, Townsend (2013) has set out to put an end to the domination of corporate visions about the future of cities. He asks his readers to stop asking how technologies are going to change the world, and instead ask 'how we are going to use our technologies to create the kinds of places we want to live in?' (Townsend, 2013: 17). Hill has remained positive about the

potentials not of smart cities but of smart citizens, powered by social media: 'We see social media-driven activism finding a foothold in the essentially ancient urban form of the square – the two work together, with the dynamics of social media manifesting themselves in these relatively open urban forms' (2013).

Ambivalence towards the smart city is by no means confined to these authors. Yet, their scepticism is noteworthy because it was these authors who first did so much to advocate for urban informatics as a mode of urban intervention and digitally-enabled urban practice. If ubiquitous, 'post-desktop' mobile computing is not as empowering as previously thought, what changed? Ten years after the field first began to claim a territory for action, intervention and change, it is worth reflecting on this. Can we now reflect, for example, on how successful smart phones have been in disrupting established urban planning regimes? In places with ubiquitous access to broadband, do urban environments exhibit trends towards different kinds of planning or governance regimes, comparative to those where effective use or access is low? Is there evidence of a correlation between device uptake and more participatory decision-making in cities? If smart cities are a worrying thing, as those such as Greenfield, Hill and Townsend have argued, did urban informatics perhaps promise too much?

Critical Appraisals

Locating the relative significance of technology disruption with the wider transformative dynamics of the urban condition has never been easy. Graham and Marvin, in their seminal work *Splintering Urbanism* (2001), highlighted this as a stubborn conceptual challenge. The problem is not just that technologies are valorised, their ability to 'impact' or 'transform' spaces repeatedly over-emphasised, but that urban spatiality itself is poorly understood. As a generation of urban geographers have come to see it, spatiality too often features as the 'empty area' *within which* social, networked relationships are formed, in which action takes place (see Graham and Marvin, 2001: 55; Soja, 2000; Massey, 2005; Lash and Urry, 1994). The instrumentalist view accords technologies of networked communication undue transformative power over space. With an emphasis on 'making the invisible visible' through new computational modes of visualisation and interaction, the risk is that pre-existing modes of urban social interaction are rendered somehow redundant, or certainly less visible.

Urban informatics has not been immune to a criticism insistent on the historical and conceptual challenges attached to urban spatial production and representation. In an essay from 2009, Williams, Roubles and Dourish, argued that many practitioners of urban informatics appeared to approach the urban environment as 'no more than an appealing design resource' and did little to address the characteristics of specific urban contexts. They argued:

> [d]esign efforts in urban informatics might best be understood as technological responses to the conditions of city life. These design values systematically favor an interpretation of the city that, consciously or unconsciously, constrains how we think about the city (2009: 2).

The authors blamed, in part, a tendency to reassert a kind of moral coherence to the city that had long been unfashionable in urban sociology. The urban imaginary embraced by the field most resembled, they argued, turn-of-the-century assumptions about the metropolis associated particularly with the work of the Chicago School, including those such as urban sociologist Lewis Wirth. This had assumed the urban form as an ideal type, or privileged basis from which to discern broad or universal claims about modernity and

society (Williams, Roubles and Dourish, 2009: 1).

This deductive method of urban sociology, seeking as it did a moral and replicable coherence to the city, was widely refuted during the radical urban unrest experienced across western cities in the 1960s (Soja, 2000: 96-7), a period that prompted the critical re-evaluation of the idea of the city as it had previously been conceived. As Crary has argued, urbanism at this time 'collided with that moment in capitalism when the rationalisation of built space became secondary to problems of speed and the maximisation of circulation' (cited in Scott, 2007: 261). The legibility of the [Western] city reached 'the threshold of oblivion' (cited in Scott, 2007: 261), as the specific spatial form of the city gave way to a mode of capitalist development (urbanisation) that was anti-territorial, or certainly not wedded to a particular ecological or spatially-confined order (Castells, 1977).

This prompted Lefebvre to declare that 'the city no longer corresponds to a social object' (2003: 57). Analysis of urban spatiality would require new conceptual tools, recognising the processes shaping the production of the built environment as now multi-scalar and generalised – something more recently discussed in the terms of 'planetary urbanisation' (Brenner, 2013). Concerned with what he saw as an emergent 'science of space', Lefebvre argued that abstracted conceptions of spatiality risked relying on old 'fixed myths of the city' prone to 'fetishising space in a way reminiscent of the old fetishism of commodities, where the trap lay in exchange, and the error was to consider “things” in isolation, as “things in themselves”'. Thus, 'instead of uncovering the social relationships that are latent in spaces... we fall into the trap of treating space “in itself”, as space as such' (Lefebvre, 1991: 90). This is why Lefebvre would write of the city as either a historical phenomenon (as in the mercantile city or the industrial city), or an image or representation that is only ever partial or, indeed, ideological (2003: 57).

Globalised processes of urbanisation would thus call into question the validity of idealised visions of the 'rational city' (Boyer, 1987). Post-war modern planning – in holding on to the potency of 'the city' as an ideal and replicable type – would ultimately be viewed, in retrospect, as somewhat tragic in its over reliance on the urban spatial form as a basis from which to alleviate social ills, seeking to reform or renew built environments while leaving social relationships and contexts intact (Tafuri, 1976: 12; Boyer, 1996: 21; Harvey, 2000: 196). The problem of 'fixing' the spatial as a sphere outside of time and historical enactment is widely known. Instead of treating space as empty 'containers for action', the effort has been to instead to focus on the urban sphere as a *process* rather than primary object of spatial analysis (see Massey, 2005; Wachsmuth, 2014).

These are stubborn conceptual challenges that the field of urban informatics can’t easily sidestep. In particular, the challenge for the field is to adequately account for the range of contextual spatial relations within which device-enabled mobile citizens interact – even if simply to acknowledge that a partial representation is all that is valid. The 'everydayness' of urban streets doesn’t mean they are simpler or more neutral backdrops for intervention. Likewise, there is perhaps much to learn from previous historical challenges associated with the enactment of progressive urban movements. For Bell and Dourish (2011), there has been a tendency within ubi-comp to focus on 'horizon technologies', which has renders 'invisible' the here and now, allowing researchers and technologists to absolve themselves of responsibility for the present, or, indeed, the recent past:

> [T]he problems of ubicomp are framed as implementation issues that are essentially someone else's problem, to be cleaned up afterward as part of the broad march of technology or to be solved by savant children (Bell and Dourish, 2011: 22).

Bell and Dourish, writing on what they have called 'the mess and mythology of ubiquitous computing' (2011), have picked up on a persistent focus on the 'proximate future'. Instead of advancing more and more 'mythology' associated with a proximate technological future, they ask, what about dealing with the messiness of everyday life? Their question feels like an appropriate one for the field of urban informatics. There may be a great deal of *potential* solutions, but how do these fare against the potential threats associated with widespread data-driven techniques of quantification, surveillance, and mass observation? How might a critical urban informatics emerge within a data-driven era of urban innovation?

Future Challenges: Synoptic Urban Sensing, Vertical-Integration and Critical Interdisciplinary Dialogues

A more governance and policy-focused discipline has been emerging in recent times, dedicated to the practical applications of urban data to improve predictive analytics engines and machine learning tools, which returns us to the establishment of CUSP. CUSP uses municipal city data as the basis for predictive modelling to guide city decision-makers. In many respects its creation signals a significant shift away from the participatory, citizen-centric ethos that has guided the experiments and interventions of urban informatics over the past few years.

Unlike many existing trials and interventions that have tended to operate at the level of a research trial or prototype, CUSP has a memorandum of understanding (MOU) with the New York City government, allowing its researchers and data science students to access government records. Its research, in the form of software and analytics, is designed to be taken up by government employees, and support the work of public agencies. Where pre-existing urban informatics labs have tended to operate through localised crowd sourced platforms and trials, CUSP has adopted the 'synoptic' lens of big data analytics. As scientists from CUSP have noted, a central task is to document and understand the 'pulse of the city', spanning mobility, energy use, communications, and economics, undertaken to both 'define the normal state against which anomalies can be judged and to understand how macroscopic city observables emerge from the aggregate behavior of many individuals' (see Dobler et al., 2015). This includes the use of astronomical techniques to analyse the dynamics of city lights, and applying physics to the study of urban phenomena and human behaviour. Researchers at CUSP have also harvested building energy data released through open data channels and combined this with the use of hyperspectral imaging and broadband infrared to generate new ways of 'seeing' the city, capturing information such as energy usage through novel data science techniques (see Dobler et al., 2015; Kontokosta, 2012). The ambitious 'quantified community' program involved the creation of data- and sensor-enabled urban neighbourhoods in New York City to promote the use of data to support urban planning and design (Kontokosta, 2015). Likewise, energy benchmarking data sourced from the NYC government has been used to create a predictive benchmarking tool for energy performance monitoring (Kontokosta, 2012). These tools are developed with the objective of supporting the city's goal of reducing carbon emissions by 80 per cent by 2050.

The use of large-scale datasets to support data-driven urban simulations, predictive modelling and city benchmarking, as is underway at CUSP, represents a new chapter in the development of urban informatics,

helping to advance the contributions of computational techniques to urban planning and governance (Bettencourt, 2013). The field is likely to attract increasing talent, enthusiasm, curiosity, and investment in the coming years. However, just as it seeks to extend the possibilities of urban informatics into the domain of urban policy, it too has provoked criticism. Townsend (2014) has written:

> At CUSP, the collection of data is decidedly big, markedly invasive, and intended primarily for researchers and their partners in government to make plans and make policy behind closed doors. It's a moon shot – with huge potential payoff, but tremendous risks and unintended consequences.

Others are likewise concerned about the widespread 'synoptic' surveillance of everyday life. Mattern has accused the new tide of urban data science of falling victim to 'methodolatry', drawing from Janesick who defines this as 'a preoccupation with selecting and defending methods to the exclusion of the actual substance of the story being told' (in Mattern, 2013: para 25). The idolisation of method means, for entities like CUSP, 'the adoration of measurement's image or representation: the knolled toolbox, the hacked perceptual machines, the scientific flowchart, the seductive data visualization' (Mattern, 2013: para 25). More recently, Mattern (2016) has linked the ambitions of CUSP with 1950s behaviourism, the too-easy linking of causality and behavioural patterns. She quotes Hannah Arendt, who cautioned that behaviourism becomes problematic when the very instruments used to measure behaviour become 'constitutive of automation and sterile passivity' (2016: para 29). These concerns reflect a growing ambivalence toward the uses of urban data more generally (extending well beyond the terrain of CUSP's own remit), where the greatest dangers lie in the widespread instrumentalisation of cities 'for data and profit' by Google-backed entities such as Sidewalk Labs. Instead of a future of smartphone-enabled citizens capable of 'reinventing cities from the bottom up', there is a growing awareness that our urban spaces may in fact be transformed into vertically-integrated stacks that allow a single, *data-copious* company to manage everything from traffic management systems, self-driving cars and navigational systems such as Google Maps. In this proximate future, some fear the asymmetries of data access between public and private entities risks destroying 'the very future of democracy' (Poole, 2014).

At this juncture, urban informatics might draw from its origins in seeking to 'ground truth' the urban possibilities of mobile-equipped citizens by extending its field of research practice beyond the device's end-user. Extending from the original interest in how apps might be used to facilitate new modes of urban interaction, more research needs to address the relationships and *contexts of use* that govern data custodians and their 'platform ecosystems'. What are the wider conditions of participation and access that govern public good outcomes of urban data? How do conditions of 'platform urbanism' (Barns, 2015), whereby platform-based business models ensure the generation of urban data largely takes place within proprietary data ecosystems, evolve to support wider social and civic goals beyond those of their business owners? Might we now ask whether the urban spaces of technology-enabled citizenship today orient us towards risks associated with vertical integration, as much, if not more so than heralding the disruptive possibilities of a participatory public sphere?

Cities will always exceed the possibilities of representation. As Sandercock (2001: 1) reminds us, cities are always 'neither organisms nor machines. They are flesh and stone intertwined. They are 'built thought': complex collections of ideas, practices, infrastructures and technologies. Against a backdrop of pervasive computing, big data, urban labs and smartphone-enabled app-tivism, urban informatics continues to evolve as a field of urban practice and knowledge-making, now confident of its ability to advance solutions

to city-scale challenges and 'age old problems'. The recent 'turn' by key proponents of urban informatics against the more corporate agenda of the smart city has also underscored the dangers of relying on digital platforms *per se* as a basis for participatory urbanism. More work, then, is now needed to support critical, longer-term engagement with the co-constitution of cities and informational spaces as complex processes, as much governed by global business strategy as lab-based technology innovation and disruptive local interventions. In any case, to refer to John Rajchman (in Massey, 2005: 159), it is always heartening to remember that a city is not only an object of data flow, or spatial syntax, or complex modelling, though it is, increasingly, all of these things; cities will always undo and exceed definitions, offering new problems for thinking and thinkers, images and image-makers, data scientists and digital refuseniks.

Biographical Note

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Notes

[1] The Centre for Urban Science and Progress (CUSP), Cornell NYC Tech and the Columbia University Institute for Data Sciences and Engineering were all supported through the Applied Sciences NYC Initiative launched under former New York Mayor Michael Bloomberg.

[2] CUSP has also been discussed by Anthony Townsend on Medium, at https://medium.com/the-new-urban-science/two-approaches-to-urban-sensing-synoptic-vs-ground-truth-b584a7285ecb

[3] Eric Paulos' 'Urban Computing' conference of 2006 is credited as one of the first events dedicated to 'urban informatics' in its present form.

[4] Differences in use between European and American approaches have been identified: European approaches use computer science and informatics interchangeably, whereas in the US informatics is more narrowly concerned with the management and analysis of data (Rosenbloom, 2013: 16).

[5] See http://urbaninformatics.net

[6] See http://senseable.mit.edu/realtimecopenhagen

[7] See http://senseable.mit.edu/realtimerome

References

- Ang, Ien and Pothen, Nayantara. 'Between Promise and Practice: Web 2.0, Intercultural Dialogue and Digital Scholarship', *The Fibreculture Journal* 14 (2009), http://fourteen.fibreculturejournal.org/fcj-094-between-promise-and-practice-web-2-0-intercultural-dialogue-and-digital-scholarship/

- Barns, Sarah. 'Platform Urbanism: The Politics and Practices of Data-Driven Cities', Presentation given to the Urban Studies Foundation Forum, University of Glasgow, April (2015), http://www.slideshare.net/sarahbarns/platform-urbanism-the-politics-and-practices-of-datadriven-cities
- Batty, Michael. *The New Science of Cities* (MA, MIT Press, 2013).
- Bell, Genevieve and Dourish, Paul. *Divining a Digital Future: The Mess and Mythology of Ubiquitous Computing* (Cambridge, MA: MIT Press, 2011).
- Bettencourt, Luis. 'The Uses of Big Data in Cities', *Santa Fe Institute Working Paper*, 29 September (2013).
- boyd, dana and Crawford, Kate. 'Critical Questions for Big Data: Provocations for a Cultural, Technological, and Scholarly Phenomenon', *Information, Communication and Society* 15.5 (2012): 662-79.
- Boyer, M. Christine. *Dreaming the Rational City: The Myth of American City Planning*, 2nd edition (Cambridge MA: MIT Press, 1987).
- Boyer, M. Christine. *The City of Collective Memory: The Historical Imagery and its Architectural Entertainments* (Cambridge, MA: MIT Press 1996).
- Boyer, M. Christine. 'The Urban Question in the 21st Century: Epistemological and Spatial Traumas' in Arie Graafland and Leslie Jay Kavanagh (eds.) *Crossover: Architecture, Urbanism and Technology* (Rotterdam: 010 Publishers, 2006), 312-332.
- Brenner, Neil. 'Theses on Urbanization', *Public Culture* 25 (2013): 85-114.
- Bruns, Axel. 'Produsage: Towards a Broader Framework for User-Led Content Creation', in *Proceedings Creativity and Cognition* 6 (2007).
- Castells, Manuel. *The Urban Question: A Marxist Approach,* trans. Alan Sheridan (London: Edward Arnold, 1977).
- Centre for Urban Science and Progress (CUSP), New York University. 'What is Urban Informatics?' (n.d), http://cusp.nyu.edu/urban-informatics/
- Centre for Urban Science and Progress (CUSP), New York University. 'The Promise of Urban Informatics', 30 May (2013), http://cusp.nyu.edu/wp-content/uploads/2013/07/CUSP-overview-May-30-2013.pdf
- Crang, Mike and Graham, Stephen. 'Sentient Cities: Ambient Intelligence and the Politics of Urban Space', *Information, Communication and Society* 10.6 (2007): 789-817.
- de Souza e Silva, Adriana. 'From Cyber to Hybrid: Mobile Technologies as Interfaces of Hybrid Spaces', *Space and Culture* 9.3 (2006): 261-278.
- Dobler, Greg, Ghandehari, Masoud, Koonin, Stephen, Nasari, R. Patrinos, Aristides, Sharma, Mohit, Tafvisi, A., Vo, H., Wurtele, J. 'Dynamics of the Urban Lightscape', *Information Systems* 54, December (2015): 115-126.
- Dourish, Paul. *Where the Action is: The Foundations of Embodied Interaction* (Cambridge MA: MIT Press,

2001).

- Ellison, Nick, Burrows, Roger and Parker, Simon, 'Editorial Comment', in Nick Ellison, Roger Burrows and Simon Parker (eds.) *Information, Communication and Society* 10.6 (2007): 785-788.
- Foth, Marcus. (ed.) *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City* (Hershey, PA: Information Science Reference, IGI Global, 2009a).
- Foth, Marcus. 'Digital Cities 6: Concepts, Methods, and Systems of Urban Informatics', Workshop Outline, *4th International Conference on Communities and Technologies*, Penn State University (2009b), http://cct2009.ist.psu.edu/workshops.cfm
- Foth, Marcus. 'Urban Informatics', *CSCW*, 19-23 March (2011), http://eprints.qut.edu.au/39159/1/39159.pdf
- Foth, Marcus, Choi, Jaz Hee-Jeong and Satchell, Christine. 'Urban Informatics', *Proceedings of CSCW* (2011): 1-8.
- Foth, Marcus., Rittenbruch, Markus, Robinson, Ricky and Viller, Stephen. *Street Computing: Urban Informatics and City Interfaces* (Abingdon, England: Routledge, 2014).
- Goggin, Gerard. *Cell Phone Culture: Mobile Technology in Everyday Life* (New York, NY, Routledge, 2006).
- Graham, Stephen and Marvin, Simon. *Splintering Urbanism: Networked Infrastructures, Technological Mobilities and the Urban Condition* (London and New York: Routledge, 2001).
- Greenfield, Adam. *Everyware: The Dawning Age of Ubiquitous Computing* (Berkeley: New Riders 2006).
- Greenfield, Adam and Kim, Nurri. *Against the Smart City (The City is Here for You to Use)* (Amazon Kindle Edition, 2013).
- Greenfield, Adam and Shepard, Mark. *Urban Computing and Its Discontents*
- (New York: The Architectural League of New York Situated Technologies Pamphlets No 1. 2007).
- Guerstein, Michael. 'Effective Use: A Community Informatics Strategy Beyond the Digital Divide', *First Monday* 8.12 (2003), http://firstmonday.org/article/view/1107/1027
- Harvey, David. *Spaces of Hope* (Berkeley and Los Angeles: University of California Press, 2000).
- Hill, Dan. 'The Street as Platform', *City of Sound* (2008), http://www.cityofsound.com/blog/2008/02/the-street-as-p.html
- Hill, Dan. 'Towards a New Architect: An interview with Carlo Ratti', *City of Sound* (2009), http://www.cityofsound.com/blog/2009/07/towards-a-new-architect-an-interview-with-carlo-ratti.html
- Hill, Dan. 'On the Smart City: Or, a Manifesto for Smart Citizens Instead', *City of Sound* (2013), http://www.cityofsound.com/blog/2013/02/on-the-smart-city-a-call-for-smart-citizens-instead.html
- Holmes, Brian. 'Counter Cartographies', in Janet Abrams and Peter Hall (eds.) *Else/Where: Mapping* (Minneapolis: University of Minnesota Design Institute, 2006), 20-25.
- Institute for a Broadband Enabled Society (IBES). 'New forms of Social Interaction through Universal Broadband Access in Public Spaces', (2009), http://broadband.unimelb.edu.au/research/community/phd3.html

- International Telecommunications Union. *ITU Internet Report 2005: The Internet of Things* (Geneva: ITU, 2005), http://www.itu.int/osg/spu/publications/internetofthings/
- Jameson, Fredric. *Archaeologies of the Future: The Desire Called Utopia and Other Science Fictions* (London: Verso, 2005).
- Jenkins, Henry. *Confronting the Challenges of Participatory Culture: Media Education for the Twenty-First Century* (Cambridge, MA: MIT Press, 2009).
- Karvonen, Andrew and Van Heur, Bas. 'Urban Laboratories: Experiments in Reworking Cities', *International Journal of Urban and Regional Research* 38.2 (2014): 379-92.
- Kindberg, Tim, Chalmers, Matthew and Paulos, Eric. '"Guest Editors" Introduction: Urban Computing', *IEEE Pervasive Computing* 6.3 (2007): 18-20.
- Kitchin, Rob. 'The Programmable City', *Environment and Planning B: Planning and Design* 38.6 (2011): 945-951.
- Kling, Rob. 'Social Informatics: A New Perspective on Social Research about Information and Communication Technologies'. *Prometheus* 18.3 (2000): 245-264.
- Kloeckl, Kristian, and Ratti, Carl. 'Enacting the Real-Time City', in Ewan Chardronnet (ed.), *Proceedings of Futur en Seine 2009: The Digital Future of the City* (Cap Digital, 2011), 72-84.
- Kontokosta, Constantine. 'Predicting Building Energy Efficiency Using New York City Benchmarking Data', *Proceedings of the ACEEE Summer Study on Energy Efficiency in Buildings* (2012), http://cusp.nyu.edu/people/dr-constantine-e-kontokosta-pe/
- Kontokosta, Constantine. 'The Quantified Community and Neighborhood Labs: A Framework for Computational Urban Planning and Civic Technology Innovation' (2015), http://ssrn.com/abstract=2659896
- Lash, Scott and Urry, J. *Economies of Signs and Space* (London, Sage, 1994).
- Lee, Douglas. 'A Requiem for Large-Scale Models', *Journal of the American Institute of Planners* 39 (1973): 163-78.
- Lefebvre, Henri. *The Urban Revolution*, trans. R. Bononno (London/Minneapolis: University of Minnesota Press, 2003).
- Lefebvre, Henri. *Writings on Cities*, trans. E. Kofman and E. Lebas (Oxford: Blackwell, 1996).
- Lefebvre, Henri. *The Production of Space*, trans. Donald Nicholson-Smith. (Oxford, UK; Cambridge, MA: Blackwell, 1991).
- Lévy, Pierre. *Cyberculture* (Minneapolis: University of Minnesota Press, 2001).
- McLuhan, M. *Counterblast* (Toronto: McLelland and Stuart Limited, 1969).
- Marvin, Simon. and Graham, Stephen. 'Ambient Intelligence and the Politics of Urban Space' in Nick Ellison, Roger Burrows and Simon Parker (eds.) *Information, Communication and Society Special Issue: Urban Informatics: Software, Cities and the New Cartographies of Knowing Capitalism* 10.6 (2007): 789-817.
- Massey, Doreen. *for space* (London: Sage, 2005).

- Mattern, Shannon. 'Methodolatry and the Art of Measure: The New Wave of Urban Science', *Places Journal*, November (2013), https://placesjournal.org/article/methodolatry-and-the-art-of-measure/
- Mattern, Shannon. 'Instrumental City: The View from Hudson Yards, circa 2019', *Places Journal*, April (2016), https://placesjournal.org/article/instrumental-city-new-york-hudson-yards/
- McCullough, Malcolm. *Ambient Commons: Attention in the Age of Embodied Information* (Cambridge: MA: MIT Press, 2013).
- MIT SENSEable City Lab (n.d). 'The real-time city is now real', http://senseable.mit.edu
- MIT SENSEable City Lab. *Real Time Rome* (2006). See http://senseable.mit.edu/realtimerome/
- MIT SENSEable City Lab. *New York Talk Exchange* (2008a). See http://senseable.mit.edu/nyte
- MIT SENSEable City Lab. *Real Time Copenhagen* (2008b). See http://senseable.mit.edu/realtimecopenhagen/
- MIT SENSEable City Lab. *The Copenhagen Wheel* (2009). See
- http://senseable.mit.edu/copenhagenwheel/
- Mitchell, William. *City of Bits: Place, Space and the Info-Bahn* (Cambridge, MA: MIT Press, 1996).
- Mitchell, William. *e-topia: Urban Life, Jim — But Not as We Knew It* (Cambridge, MA: MIT Press, 1999).
- Mumford, Lewis. *The City in History: Its Origins, Its Transformations and Its Prospects* (London: Penguin, 1961).
- Munster, Anna and Murphie, Andrew. 'Editorial: Web 2.0 is a Doing Word', *The Fibreculture Journal* 14 (2009), http://fourteen.fibreculturejournal.org/
- Paay, Jeni, Dave, Bharat and Howard, Stephen. 'Understanding and Representing the Social Prospects of Hybrid Urban Spaces', *Environment and Planning B: Planning and Design* 34.3 (2007): 446-465.
- Poole, Steven. 'The Truth About Smart Cities', *The Guardian*, 18 December (2014), https://www.theguardian.com/cities/2014/dec/17/truth-smart-city-destroy-democracy-urban-thinkers-buzzphrase
- Rheingold, Howard. *Smartmobs: The Next Social Revolution* (Cambridge, MA: Basic Books, 2002).
- Rheingold, Howard. 'Cities, Swarms, CellPhones: The Birth of Urban Informatics', September (2003), http://www.thefeaturearchives.com/topic/Culture/Cities*Swarms*Cell_Phones__The_Birth_of_Urban_Informatics.html
- Rosenbloom, Paul. *On Computing: The Fourth Great Scientific Domain*
- (Cambridge, MA: MIT Press, 2013).
- Sandercock, Leonie. 'Practising Utopia: Sustaining Cities', paper given to the annual meeting of the *International Network of Urban Research and Action* (INURA), Florence, September (2001), www.nsl.ethz.ch/index.php/en/content/download/397/2539/file
- Sassen, Saskia. *The Global City: New York, London, Tokyo,* 2nd edition (Princeton: Princeton University Press, 2001).

- Satchell, Christine. 'From Social Butterfly to Urban Citizen: The Evolution of Mobile Phone Practice', in Foth, M. (ed.) *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City*, (Hershey, PA: Information Science Reference, IGI Global, 2009), 353-365.
- Scott, Felicity. *Architecture or Techno-Utopia: Politics After Modernism* (Cambridge, MA: MIT Press, 2007).
- Soja, Ed. *Postmetropolis: Critical Studies of Cities and Regions* (Oxford: Blackwell, 2000).
- Suchman, Lucy. *Plans and Situated Actions: The Problem of Human-Machine Communication* (Cambridge/New York: Cambridge University Press, 1987).
- Tafuri, M. *Architecture and Utopia: Design and Capitalist Development*, trans. Barbara Luigia La Penta. (Cambridge, MA: MIT Press, 1976).
- Townsend, Anthony. 'Foreword', in Foth, M. (ed.) *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City* (Hershey, PA: Information Science Reference, IGI Global, 2009), xxiii-xxvii.
- Townsend, Anthony. *Smart Cities: Big Data, Civic Hackers and the Quest for a New Utopia* (New York: Norton, 2013).
- Townsend, Anthony. 'Two Approaches to Urban Sensing – Synoptic vs. Ground Truth (Pt. 1)', *Medium*, October 31 (2014), https://medium.com/the-new-urban-science/two-approaches-to-urban-sensing-synoptic-vs-ground-truth-b584a7285ecb
- Townsend, Anthony. 'Cities of Data: Examining the New Urban Science', *Public Culture* 27.2 (2015): 201-212.
- Verhoeff, Tom. 'Informatics Everywhere: Information and Computation in Society, Science, and Technology', *Olympiads in Informatics* 7 (2013): 140-152.
- Wachsmuth, David. 'City as Ideology: Reconciling the Explosion of the City Form with the Tenacity of the City Concept', *Environment and Planning D: Society and Space* 31 (2014): 75-90.
- Wallin, Sirkku, Horelli, Liisa and Saad-Sulonen, Joanna (eds.). *Digital Tools in Participatory Planning* (Espoo, Finland: Centre for Urban and Regional Studies, Aalto University, 2010).
- Weiser, Mark. 'The Computer for the 21st Century', *Scientific American* 265 (3) (1991): 94-104.
- Williams, Amanda, Robles, Erica and Dourish, Paul. 'Urbane-ing the City: Examining and Refining the Assumptions Behind Urban Informatics', in Foth (ed.) *Handbook of Research on Urban Informatics: The Practice and Promise of the Real-Time City* (Hershey, PA: Information Science Reference, IGI Global, 2009), 1-20.