1 Code and the city: introduction

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> The modern city exists as a haze of software instructions. Nearly every urban practice is becoming mediated by code.
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> (Amin and Thrift 2002: 125)

Over the past few decades, software has become essential to the functioning of cities. Urban systems and the physical and social infrastructure of the city are increasingly composed of and mediated by software-enabled technologies, and the management and governance of society framed by and undertaken through interconnecting socio-technical systems. A diverse range of public and private organisations now deploy digital technologies to monitor, regulate and control their infrastructure and the delivery of services using coded assemblages of hardware (such as chips, boards, sensors, actuators, transponders, meters, wires, batteries, screens, etc., combined into digital devices), software (e.g., firmware, middleware, operating systems, programs, apps), flows of data and interfaces, which are networked together (via various forms of Internet connections: e.g., wired, wireless, radio, satellite) (Kitchin and Dodge 2011).

Such coded assemblages now exist with respect to urban government (e.g., city services, public administration), utilities (e.g., energy, water, lighting), transportation (both car-based and public transit), public and private surveillance and security, emergency response, communications (e.g., mobile phone networks, the Internet), financial institutions and retail chains, environmental monitoring (of pollution, environmental risk, weather), and other services. All kinds of websites and apps exist – including information and data portals, crowdsourced maps and encyclopaedias, and reviews of shops, accommodation, etc. – that provide insights about urban environments, resources, services and pressing issues, as well as providing a means to source further data. A large percentage of people now traverse their cities carrying a relatively powerful computer in the form of a smartphone that hosts locative social media platforms, such as Twitter, Foursquare and Tinder, enabling and facilitating new forms of social interaction and socio-spatial behaviour, and location-based services providing spatially contextual information and recommendations.

Indeed, interacting with software has become an everyday occurrence for people, to the extent that it is mostly treated as routine and habit, operating as a 'technological unconscious' that is only noticed when it performs incorrectly or fails (Thrift 2004; Kitchin and Dodge 2011). Moreover, such is the pervasiveness of digital technologies and networks, it is impossible now to live outside their orbit, even if one possesses no digital devices and resides within an analogue home, as all key infrastructures are coded and national governments deploy digital systems in managing their affairs. Whether one is relaxing at home, travelling across a city, engaging in work, undertaking consumption, or communicating with friends and family, these are now activities that are mediated by code.

Digital technologies and services, then, are increasingly important to how we understand and plan cities, how we manage urban services and utilities, and how we live urban lives, helping to produce what has been termed 'smart cities': densely instrumented urban systems that can be monitored, managed and regulated in real time (see Townsend 2013; Kitchin 2014), whose data can be used to better depict, model and predict urban processes and simulate future urban development (Batty *et al.*, 2012), and whose deployment facilitates new forms of digital subjectivity, citizenship, participation and political action (Isin and Ruppert 2015).

And yet, despite the rapid development and deployment of digital technologies for augmenting and facilitating city management and urban life, and the creation and roll-out of new forms of networked urbanism, it is fair to say that, in contrast with the thousands of academic studies and the experimentation of companies seeking to develop, test and implement new technological products, *critical analyses* of the relationship between code and cities are small in number, underdeveloped conceptually and lacking detailed empirical case material. The speed of technological innovation and material deployment, and the power of the discursive regimes driving their adoption, is outpacing and outflanking critical reflection and intervention. Moreover, critical social scientists and humanities scholars are still struggling to get to grips conceptually with a series of interrelated phenomena – code, ubiquitous computing, big data, locative social media, mobile computing, networked urbanism and smart cities – at the same time as trying to map out and dissect their consequences and implications.

The book

Code and the City is designed to add to and extend the theoretical and empirical work conducted to date, providing both new conceptual thinking and illustrative examples of the relationship between software and the urban. It is not focused specifically on the notion and creation of smart cities, but rather on the technologies, networks and relationships that enable their production. As such, the book is interested in charting and understanding the recursive relationship between code and the city: how the city is translated into code,

and how code reshapes the city. To do this, the book brings together an interdisciplinary group of authors (from geography, sociology, media studies, cultural studies, communications, informatics and computer science), as critically examining this recursive relationship requires a variety of expertise and knowledge and for these to be bought into dialogue. As well as a range of disciplinary and theoretical perspectives, to illustrate the diversity of different coded assemblages and the coded production of space, the chapters also detail a number of empirical examples, including the Internet of Things, community wireless, locative social media and other apps, urban art installations, code libraries, search engines, geodemographics, city interfaces, hackathons and a crowdsourced emergency response.

The chapters were initially prepared for a workshop at the National University of Ireland, Maynooth, in September 2014, which was funded by the European Research Council through an Advanced Investigator Award to Rob Kitchin for *The Programmable City* (project ERC-2012-AdG-323636-SOFTCITY). The workshop met the travel costs of a carefully selected group of researchers, enabling them to attend. Each paper was drafted and submitted in advance of the meeting, extensively discussed at the workshop and subsequently revised for publication in this volume. A second volume based on a similar workshop held in September 2015, *Data and the City*, will hopefully form a companion book. To provide a structure, we have divided the book into three sections, each with five papers.

Code, coding, infrastructure and cities

The first section considers the relationship between code and the city in a broad sense, focusing on code, its production, and how it is being embedded into cities and used to reshape city life.

In Chapter 2, Rob Kitchin argues that, to date, the literature focusing on the relationship between code and the city has a number of shortcomings. He posits that studies that concentrate on code are often narrow in remit, fading out the city, and tend to fetishise and potentially decontextualise code at the expense of the wider socio-technical assemblage within which it is embedded. Studies that focus on the city tend to examine the effects of code, but rarely unpack the constitution and mechanics of the code producing those effects. To try and provide a more holistic account of the relationship between code and the city, he forwards two interlinked conceptual frameworks. The first places code within a wider socio-technical assemblage. The second conceives the city as being composed of millions of such assemblages. The latter, Kitchin contends, aims to provide a means of productively building a conceptual and empirical understanding of code and the city that scales from individual lines of code to the complexity of an entire urban system.

Much of the rhetoric and creation of smart-city technologies revolve around the production of an Internet of Urban Things and urban computing – networked devices, sensors and actuators embedded into the fabric of

buildings and the infrastructure of cities. Paul Dourish critically examines, as two parallel discourses, the Internet of Things and smart cities, in order to identify points of connection and to read the pragmatics and politics of deployment of each through the other. In the first part of his essay, Dourish traces the development of the Internet of Things and provides a set of observations concerning its networked nature, its temporality, its scaling, its operation and relations to people. In the second part, he turns his attention to smart cities, applying the same framework of observation. Dourish notes that both the Internet of Things and smart cities are plagued by tensions between holistic design and piecemeal accumulation, temporalities of development, and disparities in control and management. The consequence he contends is that, in contrast to the marketing hype, smart cities evolve in a piecemeal, gradual, disparate manner, under the control of different groups, shaped by politics, and consists of a hodge-podge of technologies using varying standards and protocols, and builds on an array of existing technology and infrastructure. There is no master plan, but rather lots of patching, hacking, jury-rigging and settling. In so much as smart cities exist, they are 'accidental smart cities'. Dourish argues that an understanding of the Internet of Urban Things necessitates examining their socio-technical assemblage, with serious attention paid to the 'technical stack', their temporalities, their politics and the participation they engender.

Much information about cities is presently accessed through screen interfaces, which present particular urban visions. Shannon Mattern critiques the 'widgetisation' of urban resources through such coded media and provides a rubric for thinking about the kinds and sources of data that underpin these systems, the design and implementation of such systems, and the people for whom such systems are created and deployed. How these coded urban dashboard and city operating systems are being deployed to produce smart cities, Mattern argues, reflects a certain kind of instrumental rationality that serves particular corporate and government interests and shifts urban vision and interaction from collective endeavour to personal consumption and convenience: translating urban sociality and spatiality 'from *our* messy city into *my* efficient city'. Mattern contends that much more consideration needs to be paid, on the one hand, to unpacking how urban interfaces are framed, designed and work, and, on the other, on how to design interfaces for urban citizens that are open, transparent, creative and imaginative and open up possibilities rather than limiting conduct and facilitating command and control. Such an approach would facilitate thinking about the relationship between technology, people and cities; what kind of cities we want and what kind of citizens we want to be in the era of smart cities.

For Matthew Fuller and Graham Harwood, the increasing use of computation to manage and control cities necessitates the production of a certain kind of abstract urbanism. Abstract in the sense that the logics of computation are underpinned by processes of abstraction, reduction and empiricism that inherently frame social and spatial processes with respect to defined

rule sets. They trace the rationale and logic of computational models of urban processes, especially simulations, back to game theory, developed in the 1940s and racial segregation modelling, from the 1960s, through to agent-based models designed to simulate how individuals of differing characteristics behave in the city under different conditions. For Fuller and Harwood, computers are abstract machines that may make claims to objectivity but are in fact thoroughly political through the choices made with regards to mathematical structures underpinning the models and encoded in software. As such, while social simulations express forms of emergence, they do so within a field of defined constraints. And yet, despite their limitations, models and modelisations are being ever-more integrated into the design and operation of city spaces and services, and urban issues are becoming computational problems. Fuller and Harwood thus argue that, as computation is increasingly embedded into urban life, and software becomes a city-making force, it is crucial that its processes of abstraction and reduction, and the consequences thereof, are exposed and examined.

In Chapter 6, Adrian Mackenzie asks and answers two key questions. In what frame and at what levels of abstraction does the density and plurality of code in the city become legible or even enumerable? What has happened to the cycling through and rewriting of code over the last 15 years? Drawing on Thrift and French (2002), he discusses three geographies of trafficking code through cities: a geography of writing code (where code writing takes place), a geography of power and control (how code defines and enacts rule of urban conduct and interlinks systems) and a geography of indeterminancy (how code produces emergent spaces). Mackenzie argues that, over the past 15 years, a reordering of code traffic has occurred, with the clustered production of code being decentred through a much more networked flow of code. He illustrates his argument through an examination of GitHub, an enormous code repository initially centred in San Francisco, but now with branches and users distributed globally. Code, he details, travels between different bits of software and GitHub acts as both a platform for social coding and a terminus for code traffic that rechannels and reshapes the code that passes through it. Mackenzie concludes that the production of code is less like a machine, a system or an assemblage but more like a crowd, and that, given the mergers, coalescences, branching and replication of bodies of code within code repositories, there is no single operational level at which code governs cities. As such, code needs to be viewed as a mixing process that reconfigures the infrastructure, logistics and circulation of individuals in cities; to make sense of such code means examining the traffic in code – how it moves and takes shape – rather than isolated pieces of software, systems or applications.

Locative social media and mobile computing

The second section considers the relationship between code, locative social media and mobile computing, focusing on how smartphones in particular and

the locative social media apps they enable are mediating how people interact with the city and each other, and how the large quantities of data generated from such apps can be used to explore and analyse these relationships.

With the rise of smartphones, location-based social media has become an increasingly popular means of documenting and mediating interactions with city spaces and places. Drawing on initial studies of Foursquare – an app that links and shares location, activity, tips and photos – and their own research of Foursquare use in Limerick, Ireland, and Sheffield, UK, Luigina Ciolfi and Gabriela Avram examine the technological support of human activities and the relationship between code, digital agency and the physical world. In particular, they explore: how location-based social networks (LBSNs) are used by individuals, and how they influence socio-spatial behaviour and frame place perception, as well as being used strategically with respect to self-presentation; and how LBSN interactions are rematerialised in the physical world and also feed back into how the software works. Their findings highlight how digital social interactions are increasingly interwoven with urban spaces and places, producing new kinds of code-mediated socio-spatial behaviours and practices.

Similarly, Leighton Evans, also focusing his analysis on Foursquare, argues that the use of location-based social media can result in deep and novel understandings of locations. He contends that the crowdsourced contributions of other users and the information pushed by the app help individuals to rapidly attune themselves to places. Drawing on Heidegger's phenomenology and Sloterdijk's theory of spheres, he explores how the moment that place is appreciated as *place* (that is, as a meaningful existential locale) can be reconciled with the delegation of the epistemologies of placehood to a computational device and location-based social media application. Drawing on data from an ethnographic study of Foursquare users, code and computational devices are contextualised as a constant foregrounding presence in the city. The engagement of the user, device, code and data in understanding place is a moment of phenomenological revelation that is co-constituent of all these elements, wherein code is the membrane that allows information to flow and influence, and yet is withdrawn and opaque to users. As such, the computationally mediated spatial behaviours of LBSNs, and thus the relationship between code and the city, operates largely beyond the circumspection of their users. Consequently, Evans argues, it is important to theorise and empirically examine the phenomenological unfolding of urban computational praxes in order to appreciate their diverse affects and effects.

Screen interfaces to interactively access, explore and engage with information are becoming an increasingly common feature of many urban spaces. In some cases, these screen interfaces are art works that layer together spaces, software, databases and interactive touchscreen technology and are designed as thinking machines to prompt critical reflection on such urban technology and the datafication and codification of urban culture. In Chapter 9, Nanna Verhoeff and Clancy Wilmott examine in detail one such art installation,

Saving Face, created by artists Karen Lancel and Herman Maat, which links a large, public urban screen with a smaller screen housed in a kiosk, wherein participants are invited to add their face to a database, with a composite image of all participants being projected on the large screen. Verhoeff and Wilmott contend that *Saving Face*, and other similar works, enable consideration of: the specificities of the use of mobile, interactive and networked media; the performativity and embodiment of engaging with such media; and how the city is reflected back into media artworks. They contend that such artworks can be understood as curatorial laboratories for embodied criticality. Moreover, as theoretical objects, they suggest that such projects allow us to investigate layering and location design principles for urban interfaces. Through their analysis, Verhoeff and Wilmott consider the dispositif of urban interfaces, the participatory agency of the individual in the act of interfacing, the installation as a public event, and the curation of cultural data and spaces. In so doing, they start to develop heuristic tools for the critical evaluation of urban interfaces or as interfaces of cultural curation.

Through an analysis of the taxi service application, Hailo, and the personal life-logging application, Moves, James Merricks White argues that it is not enough to examine the relationship between code and the city in order to understand the work and effects of these apps. Rather, he contends, they rely on a vast network of interlocking technologies with a complex spatial topology. White forwards a multilayered model, what he calls a 'socio-technical stack', consisting of four interlocking and hierarchically organised components – hardware, code, data(base) and media interfaces – designed to provide a heuristic for the critical examination of mobile applications that does not fetishise any particular layer, such as code, at the expense of others. His examination of Hailo demonstrates how the reconfiguration of hardware and telecommunications infrastructure is crucial in disrupting traditional radio-based taxi businesses and raises a number of legal and regulatory issues. Moves, in contrast, is an example of how app-generated data can exceed the software configurations in which it is represented, and provide a platform for other apps. Placing software in its wider technical stack, and framing that stack within its wider socio-technical assemblage, White contends, enables the political and economic entanglements of these apps and the mutual constitution of computation and the city to be deciphered.

Lev Manovich has been at the forefront of developing new cultural analytics – the analysis of massive digital, cultural datasets, especially those generated via social media, such as Instagram, Twitter and Foursquare, using computational and visualisation techniques. Through a series of related projects, Manovich has compared the characteristics and content of social media for different cities and how best to extract and communicate meaningful information from the millions of photos and other data generated by people within cities daily. In Chapter 11, Manovich details the process of constructing new cultural analytics for two projects. *Selfiecity* is a dataset of selfie photos shared via Instagram in five cities. To determine whether these photos

differ in style and content between cities, Manovich and his team created a number of different types of visualisations, including blend video montages, imageplots and *Selfiexploratory*, an interactive website. *On Broadway* is a multimodal, interactive data visualisation for a single street that blends together data harvested from Instagram, Twitter, Foursquare, Google Street View, taxi pick-ups and drop-offs, and economic indicators from the US Census Bureau, and plotted into 100-metre wide rectangles positioned every 30 metres along 13.5 miles of Broadway, New York. The idea is to enable citizens to explore the rich, cultural 'big data' relating to a place they either visit or live. Together, the two projects reveal the extent to which new locative social media are generating vast troves of cultural data about cities and their inhabitants. Manovich argues that while such datasets opens up the possibility of new forms of surveillance, they also create new opportunities for computational cultural analytics to inform and delight citizens.

Governance, politics and knowledge

The third section examines the urban politics of code; how it is deployed to manage cities in times of crisis, how alternative coded assemblages can be produced by communities through civic hacking, and the politics of how code is used to make sense of and produce knowledge about cities.

In times of crisis, such as an earthquake, the digitally networked infrastructure can be severely disrupted, but it can also provide a means to quickly and effectively connect and organise emergency responses both locally and globally. Monika Büscher and her colleagues discuss the latter in Chapter 12, examining digital urbanism under conditions of crisis. Drawing on the examples of the earthquakes in Haiti (2010) and Japan (2013), they detail how the use of mobile phones, Cloud computing, locative social media, distributed mapping and networked logistics were used to locate survivors and coordinate relief efforts, and enabled people located at a distance to contribute productively to localised trauma through language translation, topping up phone payments, mapping work and documenting damage. The use of new ICT technologies, and how they could rescale and reterritorialise emergency responses, has proven to be a disruptive innovation, changing established practices and taken-for-granted social and organisational conventions, economic and political models, and notions of humanity and justice. However, while these technologies have undoubted benefits, Büscher and colleagues detail that they facilitate surveillance, qualculation and automation. Moreover, they use their case studies to consider wider philosophical questions concerning the relationship between people and technology, the ethics of care, and how to design better IT for crisis response.

The majority of smart-city initiatives that deploy coded infrastructure are owned and managed by companies and states and are deployed through top-down governance via systems of centralised control. Alison Powell, in contrast, considers alternative, bottom-up, participatory visions of the

relationship between code and the city and what they might mean for the governance of urban space. She does so through an examination of peer-to-peer urbanism, as produced through the discourse, practices and architectures of community wireless networks, which are owned and run by local communities. Such peer-to-peer networks, Powell contends, enact a 'politics of the minor' – localised political interventions that disrupt the dominant order – and create new forms of technological citizenship. They therefore illustrate the possibilities of alternative ways of producing coded cities that have different organisational practices, modes of architecture, political sensibilities and spatial formations. However, they are also vulnerable to erasure or absorption by the dominant order, as has happened with many community wireless networks. Nonetheless, they highlight that there is no teleological inevitability to how smart cities will unfold.

Hackathons and civic hacking have become popular events in which individuals collaborate to produce technological solutions to urban problems. Sophia Maalsen and Sung-Yueh Perng examine how hackathons take place, how the coding produced within them seeks to address urban problems, and the implications and challenges that emerge in that process, by drawing on their ethnographic participant observation of Code for Ireland events in Dublin, Ireland. In particular, Maalsen and Perng focus on the placing of hackathons, examining the role of the venue, its spatial arrangements and the fluidity and messiness of the hackathon process, the relationship between individuals and the collective hack, and the productive tension between what the participants want to do and what the government or companies running the hackathon desire. In the process, Maalsen and Perng reflect on how hackathons seek to translate the problems of the city into apps that seek to provide answers and, in turn, transform ways of living. They conclude, however, that the events are often more effective in facilitating networking and providing a social experience than producing apps that effect change.

Heather Ford and Mark Graham examine how places are codified in data and data structures, and linked and represented through the Semantic Web, to produce digital representations that augment knowledge about cities. In particular, they focus on Google's Knowledge Graph, which links, structures and shares data from Wikipedia, UNdata and other sites, to provide snapshot information about places in relation to searches without the need to visit other sites. In combination, Google and Wikipedia's algorithms and databanks determine how a city is presented. This is far from a neutral process, however, with a locale's political context often embedded into its digital layers. Ford and Graham illustrate this by examining how different language versions of Wikipedia, as well as Wikidata, Freebase and Google, present information about Jerusalem, a highly contested city. Their analysis highlights how the intersections of people, practices, tools, laws, and geopolitics produce different, contested codified versions of Jerusalem, depending on language version (English vs Hebrew vs Arabic), but that nuances, provenance, agency of

editors and transparency in politics are often obscured. Ford and Graham conclude that the messy political informational layers of cities are presently becoming more accessible to machines and more opaque to humans; structured to enable an automatic production of geographical knowledge, but one that obscures heterogeneity and presents a narrowly framed view of cities.

Alex Singleton's chapter provides a detailed illustration of the abstract urbanism identified by Fuller and Harwood, presenting the codification of geodemographic classifications, their history and their use. Geodemographic models group areas into categories based on shared population and built-environment characteristics, using practices of abstraction, reduction and representation. These models are then used for a variety of purposes, including area-based social policy formulation and targeted marketing, having diverse effects on city life. Singleton details how constructing these models is both a science and an art, involving the use of statistics and computation, but also builder judgement and experience to create classifications that seemingly best represent the characteristics of a place. He also details how the models can be influenced by scaling, zones, input variables, measurement, weights, transformations and clustering methods. Singleton illustrates the effect of the geographical extent of the classification boundaries on the geodemographics produced by comparing the same method applied to the UK and Liverpool. He argues that such urban codification has great utility, but also that the methods deployed to create them need to be open in nature so that the process of abstract urbanism is transparent and open to scrutiny and challenge.

Code and the city

Taken together, the chapters highlight the diverse ways in which the city and code are being co-produced and how this, in turn, is reshaping urban infrastructures, management, knowledge and living. Several themes that cut across the chapters advance the debate as to how best to make sense of the relationship between code and the city. We highlight three that we think demand particular attention.

First, what is at stake is the transformation of urban infrastructures, knowledge and everyday practices through their enduring and emergent associations with code. There is a pressing need, then, to understand the nature and work of code in the city. At the same time, we need to be mindful of fetishising code at the expense of the full socio-technical assemblage that constitute digital technologies and their enactment. Software-enabled technologies consist of amalgams of infrastructure, hardware, operating systems, software and data that are bolted together and work in conjunction to perform their work. How the city is rendered as models and captured in code as algorithms is a crucial element in the reterritorialisation of the city through a computational or mathematical logic (see Chapter 5). This abstract urbanism is, however, enacted through coded assemblages that work in contingent and

contextual ways, dependent upon a range of social, cultural, political, legal and economic forces that shape how they are constructed and operate (see Chapters 2 to 4 and 10). These coded assemblages have varying temporalities and scalings (see Chapter 4), there is a geography and sociology to the process through which they are created (see Chapters 6, 13, 14 and 16), and they work not in isolation but in relation to other coded assemblages to create a dense network of coexisting, collaborating and competing infrastructures and systems.

Second, these assemblages are not flat ontologies, composed of horizontal, equally weighted networks of association. Nor are they neutral, objective, non-ideological in their conception and functioning. Rather, they are full of politics and power, and asymmetrical, hierarchical and contested relations (see Chapters 4 and 12 to 15). Digital technologies operate within, recast and reproduce political economies: they form the apparatus of the state, the engines of capital accumulation for business, and can be deployed and recast in acts of resistance and transgression by citizens. They are created to enact the desires of their producers and deployers and are expressions of power that work to (re)produce particular socio-spatial configurations, at the same time as they are challenged and subverted (see Chapters 13 and 15).

Third, there is a performativity to the creation and enactment of coded assemblages, with them unfolding in contingent, relational, contextual and embodied ways (see Chapters 6 to 9). There is no teleological inevitability or set path dependency to how digital technologies transduce and reterritorialise cities; how they are created, deployed and used; how they produce and communicate geographical knowledge; and how they enable new forms of spatial behaviour and place making (see Chapters 7 and 8). Rather, they emerge and evolve through diverse practices, often in piecemeal, distributed, embodied and disparate ways (see Chapters 3, 12 and 13), but also through more carefully delineated but nonetheless emergent processes (see Chapters 6, 11, 15 and 16).

Taken together, these three observations point to the need for critical scholarship that can encapsulate two outcomes that are often difficult to achieve simultaneously. On the one hand, there is a need for more holistic accounts that seek to place the relationship between code and the city in a wider context. On the other, there is a need for detailed, nuanced, empirically rich accounts that tease apart complex, contingent, relational processes and unpack how coded assemblages are formulated, produced and work. Moreover, much more normative and ethical thinking needs to take place with respect to what kinds of coded cities we wish to build and inhabit. Collectively, we believe the chapters in *Code and the City* produce such breadth and depth and begin to map routes for thinking creatively about future socio-spatial relations, providing useful insights into how digital technologies are enabling new forms of programmable urbanism. We hope that you similarly find the book a stimulating, informative and constructive read.

Acknowledgements

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