Chapter 1
Computational Approaches for Urban Environments: An Editorial

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Abstract Cities are under continuous pressure due to an increasing urbanization which will have far-reaching consequences for housing, transportation, retail, etc. To cope with these challenges, methodological advances in quantitative modeling coupled with growing amounts of spatial and spatiotemporal data can add significantly to our understanding of how cities function. Because the added value of data-driven approaches to analyze urban environments is promising but still in its infancy, the present volume aims to promote the application of advanced computational methodologies to achieve a better understanding of our cities and the underlying mechanisms.

1.1 Prologue

Today's cities are highly complex, dynamic, and vibrant environments subject to frequent changes. The impacts of globalization, information economies, as well as social and demographic changes, among others, have given cities a distinct appearance (e.g., Hall 1993; Batty and Longley 1994; Anas et al. 1998; Batty 2013; Fujita and Thisse 2013). Urban environments are places where most of the people in our contemporary society live. In addition, the United Nations (2014)

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predict that the worldwide proportion of people living in urban environments will double by 2030 compared to the 1950s. According to this trend, in Europe, for instance, the percentage of the population living in urban areas increased from 1950 to 2007 from 42 to 72 %. More important is that this trend of urban growth will continue within the next one or two decades. The United Nations forecast that the European urban population will increase to more than 78 % until 2030. Without doubt, these urbanization processes, due to their far-reaching impacts on the economy, climate change, and health, among others, will intensify the pressure on cities and urban societies even more. In order to be prepared for and to manage these future challenges, well-thought-out planning and policy strategies are required (Shafizadeh-Moghadam and Helbich 2015; Clarke 2014). In this regard, quantitative modeling can add significantly to our understanding of how cities function. Equally important is to undertake research linking cities with computational approaches and put such research on policy agendas throughout the world.

As discussed by Pacione (2009), urban environments are highly multifaceted areas consisting of several subcomponents, including housing markets (e.g., Helbich et al. 2013a, c), transportation systems (e.g., De Vos and Witlox 2013) etc., shaping our cities across different scales. Each of these components comprises of its own spatial and spatiotemporal patterns and processes. As indicated in Fig. 1.1, the complexity is further amplified through interrelationships between these individual components. For illustration purposes, let us examine the following example: We assume that the accessibility of an urban fringe is improved by means of a highway construction. Due to this new transportation infrastructure provision, the improved linkage between the suburbs and the core city reduces commuting time and thus makes these metropolitan outskirts more attractive for new residents to move in. This accompanied increase in the demand for new residential areas results in raising suburban land and housing prices, which makes residential land affordable for higher-income classes, only. This rather simple example illustrates that the components of urban environments are highly connected to each other and comprise of interrelated feedback loops.

Although cities have been widely studied during the last decades and meticulous research dealing with economical, infrastructural, environmental, political, social,
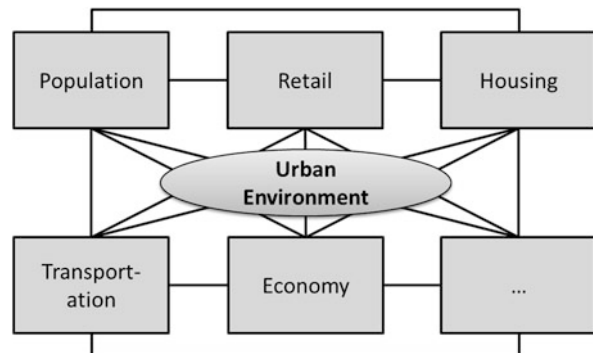

Fig. 1.1 Components of urban environments

and demographical aspects has been piled up promoting and supporting our understanding of the operation of cities (e.g., Batty 2008, 2013; Bettencourt 2013; Glaeser 2011; Clarke 2014), the underlying processes and the interactions between components are only partly understood thus far. Several academic disciplines are dedicated to urban research. Each of them has their own unique perspective on cities and utilizes their unique set of methods and tools. This results in fragmented knowledge and a lack of coherent insights (Solecki et al. 2013). While qualitative urban research has added significantly to the understanding of cities, past empirical quantitative research has benefited from advances in the field of geographic information systems (GIS; Goodchild 2010) technologies. At present, GIS-based analyses (e.g., Jokar Arsanjani et al. 2014) have reached some level of maturity and are an integral part of spatial sciences as well as of urban policy- and decision-making. Although the quantitative analysis of urban areas is not new and goes back to the quantitative revolution in geography (see Kwan and Schwanen 2009), the rapid methodological progress – including spatial statistics, remote sensing, data mining, and simulation-based modeling, among others – coupled with the recent accumulation of readily available spatial and spatiotemporal data on a detailed scale, i.e., volunteered geographic information (e.g., Jokar Arsanjani et al. 2013a), airborne laser scanning data (e.g., Xu et al. 2014), and cell phone data (e.g., Calabresea et al. 2013), among others, has stimulated and shifted the emphasis to a computationally oriented urban science (Batty 2013).

In the literature, this linkage between geography and computational science (Lazer et al. 2009) is referred to as geocomputation, coined by Openshaw and Abrahart (2000). While the prefix "geo" emphasizes that geocomputation deals with spatial theories, georeferenced data, and spatially explicit research problems, the latter term "computation" highlights how geographical science is conducted, namely, through a broad spectrum of computer-intensive methods, mathematical and spatial statistical models, simulations, etc. Thus, geocomputation aims to explore, extract, and generalize inherent urban patterns and processes, in data-driven fashion from spatial and spatiotemporal data to not only solve complex geographical urban problems but also to transform the implicit and hidden information in spatial databases into urban knowledge. As such, geocomputation is an umbrella term that includes, but is not at all limited to, agent-based modeling (e.g., Jokar Arsanjani et al. 2013b; Torrens 2012; Malleson et al. 2013), cellular automata (e.g., Vaz et al. 2012; Pijanowski et al. 2014), spatial (e.g., Helbich and Leitner 2012) and spatiotemporal cluster detection (e.g., Nakaya and Yano 2010; Hagenauer and Helbich 2013a, b), Bayesian models (e.g., Brunauer et al. 2013; Law and Quick 2013), fuzzy logic (e.g., Grekousis et al. 2013), local regression modelling (e.g., Leitner and Helbich 2011; Helbich et al. 2014), regionalization (e.g., Wang et al. 2012; Helbich et al. 2013c), and neurocomputing coupled with or without evolutionary algorithms (e.g., Arribas-Bel et al. 2011; Gu et al. 2011; Hagenauer et al. 2011; Helbich et al 2013b; Mimis et al. 2013). For a more detailed and thought-provoking theoretical discussion, the reader is referred to Couclelis (1998), Fischer (2006), as well as Birkin (2009).

However, nowadays the added value of the applications of cutting-edge computational approaches to analyze urban environments is promising but still in its infancy and far from being mainstream. Therefore, the editors of this volume believe that this book adds to the contemporary research agenda on cities from an interdisciplinary point of view and highlights the large potential of data-driven techniques to better understand how the individual urban subcomponents function and how cities as a whole operate. As such, it seems that the full potential of geocomputational approaches is still not entirely explored and more research is necessary. In this regard, the chapters in this volume make use of the ever-increasing and more precise geospatial urban data and linking them to up-to-date computational techniques (Miller and Goodchild 2014). This is consistent with the urgent call by Solecki et al. (2013) for a computationally integrated "urban science." As a consequence, this allows to formulate new and/or alternative hypotheses as well as to establish novel and universal "urban laws and theories." The authors hope that this edited volume can add to this recent trend that has been observed in the literature.

1.2   Objectives

The present volume entitled *Computational Approaches for Urban Environments* deals with the synergic usage of advanced computational methodologies in close relationship to geospatial information across cities of different scales. The main objective is to promote recent advances in the application of computational methods, beyond traditional urban analysis, to achieve a (hopefully) more appropriate understanding of the inherent complexity of our cities and underlying mechanisms. In doing so, the book seeks to offer a complementary perspective to the large body of literature dealing with the analysis of urban environments. To achieve more holistic insights into cities, their dynamics, shapes, morphologies, and residents, this collection of chapters subsumes research originating from disciplines such as geography, economics, computer science, statistics, geographic information science, remote sensing, and urban planning. It is anticipated that this book shades light on and contributes to contemporary problems cities are faced with and how it would be possible to tackle them to offer urban decision- and policy-making a sound and solid basis of understanding. The collection of chapters provides a selection of actual computational approaches useful for, but not limited to, audiences that include researchers, postgraduates, and professionals.

As indicated by the high response for the call for chapters, it appears that the intention of this book received wide approval. By the end of June 2013, a total of 32 chapter proposals were submitted. After an internal review by the editors, 30 authors of those originally 32 submitted proposals were invited to submit a chapter manuscript. After the final chapter submission deadline on November 1 2013, a total of 26 manuscripts were submitted. Subsequently, each of the 26 chapter manuscripts was evaluated through a *double-blind review process* by at least two international experts. For the review process, the standard Springer review guidelines were used. Besides the innovative aspect of the research, the scientific quality of the research

weighted heavily on the decision whether or not a manuscript was accepted or rejected. In cases where major revisions were requested by the reviewers and to guarantee high scientific quality, a second round of review of the revised manuscript by one of the original reviewers or an alternative reviewer was conducted. If the reviews called for minor revisions, then a second round of reviews was not done. Instead, the editors made the decision whether or not the revised manuscript was fit for publication. In April 2014, 14 chapters were accepted and are now included in the present book.

1.3 Structure of the Book

The book integrates several areas of urban environments, each associated with a main theme of the book. The present volume has the following five sections: (1) spatial planning and decision-making, (2) housing and real estate, (3) urban transportation and mobility, (4) remote sensing, and (5) urban sensing, social networks, and social media. However, this structure should not be understood as fixed and definitive. Quite the contrary, the boundaries between these sections are partly fuzzy and overlap each other to some extent.

Part I on *Spatial Planning and Decision-Making* includes three chapters. Chapter 2 by Pierre Frankhauser reviews fractal geometry to explore the spatial organization of urban fabrics. He demonstrates how existing planning concepts can be enriched through fractal analysis. In Chap. 3, Martin Behnisch and Alfred Ultsch present an approach coupling machine learning and data mining techniques for discovering patterns in multidimensional building and land use data for urban districts in Germany. It is demonstrated how these techniques may serve as hypothesis generators for planning purposes. Closely related to this chapter is Chap. 4 by Julian Hagenauer. He proposes a method for clustering spatial data by integrating contextual neural gas and graph clustering. The efficiency of the method to derive meaningful and theoretically sound regions is demonstrated on synthetic data and a real-world case study dealing with demographic and socioeconomic data for Philadelphia (USA).

Part II deals with *Housing and Real Estate* and comprises of three chapters. In Chap. 5, Alexander Razen et al. review recent developments in structured additive regression models. Besides a multilevel structured additive regression for location scale and shape, a Bayesian version of the quantile regression is proposed. Investigating owner-occupied single family homes in Austrian urban areas, nonlinearities in the hedonic price function and spatial heterogeneity, among others, are observed. Next, in Chap. 6, Shipeng Sun and Steven Manson highlight the importance of the housing search in the context of intra-urban migration of domestic residents. In order to simulate the complex location decision-making, an agent-based model is formulated and validated against real-world housing vacancies for the Twin Cities of Minnesota (USA). The case study demonstrates how realistic intra-urban migration patterns emerge from rather simple behavioral rules of home searchers. Chapter 7 in Part II is written by Timothy Rosner and Kevin Curtin. The authors examine Jane

Jacobs' four generators of urban diversity – dwelling density, block length, mix of building age, and mix of uses – and develop a new composite urban livability index to measure social and economic characteristics of the built environment. The capability of the index is tested for the District of Columbia (USA).

Part III deals with another component of urban environments, namely, *Urban Transportation and Mobility*, and includes two chapters. In Chap. 8, Godwin Yeboah et al. propose a space-time analytical approach based on analyzing global positioning system data for cyclists. In addition, they advance policy strategies in Newcastle (UK) to improve cycling uptake as well as data processing methodologies through gaining a profound gender-based understanding of cycling behaviors. In contrast, Rashid Waraich et al. identify in Chap. 9 the challenges of utilizing agent-based traffic simulation frameworks. Focusing on the MATSim software environment, several methods to improve the simulation performance through a combination of reducing disk access, decoupling computational tasks, and making use of parallel computing are proposed. Additionally, an event-based model instead of a fixed time increment approach for the traffic simulation is propagated.

Remote Sensing advances and applications are the focus of Part IV, comprising of four chapters. In Chap. 10, Konstantinos Karantzalos gives a comprehensive review of the state of the art in the field of change detection to monitor the growth trajectories of urban areas. Essential change detection components, unsupervised and supervised classification methodologies, and object extraction, among others, are discussed in this chapter. On the contrary, Chap. 11 by Christian Berger et al. presents a data fusion technique in which airborne hyperspectral and light detection and ranging (LiDAR) data are combined in order to derive an urban surface material map required for a microclimate model. Two case studies underpin the potential of data fusion to derive key input parameters in this research domain. In Chap. 12, Junmei Tang monitors the spatiotemporal urban expansion of Houston's metropolitan area applying cellular automata models. It is concluded that the incorporation of socioeconomic data improves the predictive accuracy to simulate the growth of human-intervened landscapes.

Part V on *Urban Sensing, Social Network, and Social Media* contains three chapters. To begin with, in Chap. 13, Yaoli Wang et al. utilize mobile cell phone data from a Chinese city to investigate how social networks are embedded in the urban physical space. For instance, the authors find that higher degree users in the telephone contact network tend to congregate in the central business district and that the downtown area hosts many heterogeneous communities of social groups. In Chap. 14, Emily Schnebele et al. propose to integrate volunteered geographic information and social media data with authoritative sources to fill data gaps during environmental emergencies. Two applications are presented. While the first study applies an artificial neural network to transportation infrastructure flooding, the second study deals with the usage of mobile phone data during emergency evacuations. In Chap. 15, Sebastian Grauwin et al. look at the possibility of mapping space-time human activities in urban environments in the metropolises of New York, London, and Hong Kong based on the detection of mobile phone usage (i.e., number of calls, SMSs, and data transfers). The authors provide insights into both the

universal structure of cities and the cultural, technological, and economical factors shaping human dynamics. Clustering identifies locations with similar patterns. Their findings confirm that while the economy becomes more global, common patterns emerge in business areas of different cities across the globe.

The final chapter by Paul Longley reflects about the potential of computational approaches discussed in this book, observes current development trends, and frames future research challenges. To sum up, the chapters introduced above tackle a variety of aspects of cities by means of innovative computational approaches. The collection of chapters indicates that cities are far too complex to deal with them from only one point of view and one set of argumentations. In addition, it is important to learn that different methodological and theoretical approaches enrich and complement each other. In this regard, it is desirable that the scientific outcome of this book will stimulate urban-related international and interdisciplinary research networks, paving the way to bring us closer to Michael Batty's (2013) vision of a "new science of cities."

Last but not least, the editors must express their gratefulness and gratitude to all reviewers for their support and their critical and constructive comments for each chapter. This has added significantly to the quality of the entire volume. We deeply appreciate the efforts of all authors, who submitted a full chapter manuscript and selected our book as a potential publication outlet for their research. Furthermore, we thank Mei-Po Kwan and Paul Longley for their comments. Marco Helbich and Jamal Jokar Arsanjani thank the Alexander von Humboldt foundation and Heidelberg University, Germany, for laying the foundation for this book. Finally, we acknowledge the Springer team as well as the series editors Jay D. Gatrell and Ryan R. Jensen for their great assistance throughout the whole publication process. Without all these helping hands, this volume would have never been published.

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