Chapter 39
Introduction to Urban Computing

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Abstract This chapter overviews Part V of this book themed urban computing. This part of the book covers the topics of visual analytics, cloud, edge, and mobile computing, data mining and knowledge discovery, AI and deep learning for urban computing, and a range of mainstream urban models and simulation methods. It provides a systematic review of computing technologies for urban governance and urban services, together with the examples of their usage, in the context of urban computing.

Within the context of urban informatics, urban computing is the processing of acquired urban data to serve urban applications. Urban computing can be regarded as the use of computing technologies to address urban issues, including those for urban governance and providing services to urban people. The computing technologies include those that are relevant to urban-related data communications, governance, analyses, mining, and visualization.

The basis of urban computing is the capability to perform highly scalable, fast, reliable, and flexible computation. The advances in cloud, mobile, and edge computing have greatly enhanced the computation capability for urban applications. Urban governance aims to improve the effectiveness and efficiency of urban management and decision making by addressing urban issues like traffic congestion, environmental pollution, disaster mitigation, aging population, large infrastructure maintenance, and housing. Urban services aim to provide a better experience for citizens in daily life. To achieve the goals of urban governance and urban services, urban computing needs to help people understand the data and extract actionable knowledge or other analytical results for alleviating urban issues and providing services. This leads to more dimensions of urban computing: urban data mining, analytics, modeling, and simulation.

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The chapters in Part V of this book describe urban computing from the perspectives of principles, models, and technologies in computing science and urban modeling. Emphases are put on the development and use of these principles, models, and technologies for urban contexts and urban applications.

While computations are carried out by machines, humans are the ones utilizing the computations to make decisions. Thus, Chap. 40 by Gennady Andrienko and 14 colleagues first introduces visual analytics, the study of the principles and methods for human-computer collaboration in solving complex problems, with a focus on visual analytics for urban mobility data. The chapter describes various visual and interactive analytical techniques and exemplifies the use of these techniques by analyzing Europe-wide data on the movement of passenger cars. By doing so, it shows how visual analytics greatly improve the ability of humans to see, interpret, link, and reason with data and their computation results, and then make decisions in urban contexts.

Chapter 41 by Chaowei Yang and his team introduces three backbone technologies for urban computing: cloud, mobile, and edge computing. Cloud computing provides scalability and on-demand availability of urban data computation. Mobile computing shifts the computation to mobile devices to reduce the load on central computation and enable more social interactions of citizens. Edge computing moves the computation to sensor networks to dramatically reduce the data communication load, speed up the response of sensors, and alleviate data-safety issues. The chapter systematically reviews the principles and characteristics of the three computing technologies and their applications in smart cities, and further illustrates their uses and integration by using the example of the urban heat island.

Chapter 42 by Chao Zhang and Jiawei Han moves to extracting succinct and easily interpretable knowledge from massive urban data. The review concentrates on discovering knowledge about urban activities from a type of crowdsourced and less-structured urban big data, that is, social sensing data contributed by users who share their experiences in the physical world online. The chapter first describes conventional and recently developed statistical and pattern-discovery methods for urban activity modeling, then presents the latest multimodal embedding techniques for learning urban activities, and concludes with future directions of urban knowledge discovery.

In the data-intensive era, approaches of mining knowledge from urban big data inevitably progress to leveraging the latest developments of artificial intelligence (AI), especially deep learning. In Chap. 43, Senzhang Wang and Jiannong Cao provide an overview of the challenges, methodologies, and applications of AI for urban computing. The chapter introduces the principles of mainstream AI techniques for urban computing, including popular deep-learning models that are commonly used in urban computing tasks. Then, the authors review the wide applications of urban computing based on AI and deep learning in urban planning, urban transportation, social networks, urban safety and security, and urban environment monitoring.

People use various urban models to understand cities and carry out urban governance and urban service tasks. The models run on real-world data with realistic complexity, as well as on simulation data that can overcome the sparsity of real-world data and be obtained with much lower cost and risk (e.g., for a disaster evacuation scenario). The remaining chapters in Part V introduce a number of mainstream urban models and simulation methods.

Chapter 44 by Mark Birkin presents microsimulation, the technique for generating synthetic population data of humans, households, or other entities at the individual level by using aggregate census data and individual-level sample data. Then, such synthetic data can support more analysis functions and result in deeper insight into the investigated problem than the original aggregate census tables. The chapter describes the principles of microsimulation, followed by the properties of microsimulation in computation, uncertainty, data assimilation, dynamics, and interdependence.

Chapter 45 by Anthony G. O. Yeh, Xia Li, and Chang Xia discusses cellular automata (CA) modeling for urban issues. With its unique strength in simulating complex nonlinear problems, CA has become a major analytical approach for creating what-if scenarios to facilitate urban policy making. The chapter covers the basics of CA models, the approaches to using CA models for urban modeling, different types of specialized urban CA models, applications of CA in urban studies and planning practices, and finally an outlook on further research for solving the remaining problems in urban CA modeling.

Chapter 46 by Andrew Crooks, Alison Heppenstall, Nick Malleson, and Ed Manley reviews agent-based modeling, the simulation technique that can create artificial worlds populated with individual agents, and investigate macroscopic processes in cities formed by interactions between the agents. A distinct advantage of agent-based modeling is its ability to assign diverse behaviors and rules to individual agents or groups of agents, which makes it a powerful way to simulate complex urban problems. The chapter presents the fundamentals of agent-based models and the applications of these models for solving urban problems. It further discusses how to capture decision-making processes in agent-based models, and new advances in agent-based modeling by utilizing big data, data mining, and machine-learning techniques.

Traveling and transportation have always been core topics in urban modeling. Chapter 47 by Eric J. Miller discusses the all-around evolution of transportation modeling driven by informatics. The chapter probes into this evolution from the changes in travel behavior due to real-time travel information and new mobility services and technologies; changes in transportation-system performance; new survey and tracking data available for transportation modeling; and the progress of modeling methods in response to new transportation phenomena and the latest computing and AI technologies. Finally, the chapter foresees new research problems where the theories and big data collide, that may fundamentally change transportation modeling in the future.

Due to space limitations, Part V only addresses a selection of core topics of urban computing. Many other important topics could be elaborated, for instance, urban data communication which is crucial for cloud, mobile, and edge computing. Urban data communication technologies include those for data transmission, wired and wireless data communication networks, devices, protocols, and security issues.

Also, the theories of modeling cities as complex systems have been discussed in Part I of this book, but much more discussion is needed on the computational aspect of complex system modeling for cities, particularly complex network modeling. Complex network models have been used not only on the topics traditionally employing network models, such as vehicle movements or road networks, but also on all kinds of dynamics and interactions in cities.

People will not stop pursuing higher computation capacity. Quantum computing, the computation based on principles of quantum mechanics such as superposition and entanglement, is a prominent example of the technologies in the experimental stage that aim to exponentially accelerate computation. Once some of these technologies become widely available, they are also likely to be applied to urban issues and to stimulate revolutions in urban computing.