Towards Integrated Urban Simulations

Irene Meta*†, Fernando Cucchietti*,
*Barcelona Supercomputing Center (BSC), Barcelona, Spain
†Universitat Internacional de Catalunya (UIC), Barcelona, Spain
E-mail: {irene.meta, fernando.cucchietti}@bsc.es

***Keywords*—urban simulations, holistic approach, urban areas, future city.**

I. Extended Abstract

More than half of the world population lives in urban areas. Urbanites are estimated to grow up to 68% of the population by 2050 [1]. This rapid growth requires new contributions from researchers and policy-makers to the development of the future city. Again, understanding how the city will grow is a crucial step in guiding this process towards the best outcome.

Cities are highly complex systems that traditional urban dynamic simulations cannot grasp in their totality, if solved only in a lightly coupled way. In addition, a model is useful only if it can be used in the planning and management practice [2]. It's true that, driven by the urge to improve their models, different sectors are developing multi-layered integrated simulations. Nevertheless, a wider scope of considering the city in its holistic behaviour is missing. Indeed, management, social, and technical barriers restrain the adoption of integrated models, such as 'model complexity, user friendliness, administrative fragmentation and communication' [3].

Simulation models are the test field where to evaluate the mechanisms of how urban systems work, according to different settings and changing conditions [4]. They allow impact assessment for new urban policies and development goals, as well as the evaluation of ongoing ones [5]. With virtual models, planners can test and evaluate changes that, otherwise, are (i) costly, (ii) unethical when people are implied and (iii) whose effects may delay appearing.

The first stage of this research consists of studying the progress made towards integration in each urban system (that we consider 'layers'). To do that, we need to (i) identify these and (ii) develop a methodology to compare integrated models belonging to the identified urban systems.

To identify the layers the city is made of, we start from the City Anatomy [6] research. Indeed, there is no common definition of city, that evolves around political, economic, and social ideas [6]. In Ref. [6] the city is considered 'a system of systems and interactions that foster emergent human behaviour. The city is compared to an organism: the capability of working together and in coordination leads to more than the sum of the individual systems (or layers).

Starting from the Anatomy described in [6], the urban systems are translated into nine layers: the six 'infrastructures' that enable flows from/to and within the city ('Communication Network', 'Water Cycle',' Energy Cycle', 'Matter Cycle', 'Mobility Network' and 'Nature'), the 'Built Domain', the 'Society', and the 'Environment'.

After having defined the layers, we define a methodology to categorize and compare existing models. These two steps are recursive: in defining the categories, we gain new insights to better translate the urban systems from [6] into layers.

In the process of comparing we consider both Deterministic and Statistical models, and we exclude virtual three-dimensional models that offer only a visualization of the planning distribution.

Deterministic models are 'theory-based' [4] (or 'secure' models according to [7]), where the relationship between model and theory is recursive: models test the theory they are based on and are used to define a better one [4]. Statistical models are 'black-box' or 'theory-laden' [4] models (see 'insecure' models [7]) where the results obtained are more important than the behavior of the simulation algorithms, that may be not fully understood.

We collect examples for every and each layer and according to different categories, which take into account the subject that is modelled, whether the model aims to develop a theory or to exploit one, which simulation technique is used and to which purpose, the temporal and spatial capabilities of the simulation, the data requirements and availability, and the integration and interaction processes [4], [8], [3].

As a result, we conduct an extended review according to the nine layers. The definition and gathering of these categories should help identify which are the open problems yet to solve in the simulation field. From there, we're planning the future development of sustainable mobility simulation.

Acknowledgment

The references analysis was partially developed in collaboration with IAAC - Valldaura Labs (Institute of Advanced Architecture of Catalonia). We want to thank Vicente Guallart and Dr. Diego Navarro for the insightful discussion.

References

[1] P. D. United Nations, Department of Economic and Social Affairs, "World Urbanization Prospects: Key Facts of the 2018 Revision."

[2] E. Miller, "Integrated urban modeling: Past, present, and future," vol. 11, pp. 387–399.

[3] P. M. Bach *et al.*, "A critical review of integrated urban water modelling – Urban drainage and beyond," vol. 54, pp. 88–107. [Online]. Available: http://www.sciencedirect.com/science/article/pii/S1364815213003216

[4] M. D. Kilbridge *et al.*, "A Conceptual Framework for Urban Planning Models," vol. 15, pp. B–246. [Online]. Available: https://pubsonline.informs.org/doi/abs/10.1287/mnsc.15.6.b246

[5] V. Couture *et al.*, "Income Growth and the Distributional Effects of Urban Spatial Sorting," p. 59.

[6] Guallart *et al.*, "City Anatomy: A Framework to support City Governance, Evaluation and Transformation."

[7] S. Bullock, "Levins and the Lure of Artificial Worlds."

[8] S. Berling-Wolff and J. Wu, "Modeling urban landscape dynamics: A review," vol. 19, pp. 119–129. [Online]. Available: https://doi.org/10.1111/j.1440-1703.2003.00611.x

Irene Meta Graduated with honour in 2016, holds a Master in Architecture from the Polytechnic School of Genoa (Italy). She receives a mobility grant to focus on Big Data and Smart City technologies for mobility applications at BSC (Barcelona Supercomputing Center – Centro Nacional de Supercomputación). She later joins the IAAC (Institute of Advanced Architecture of Catalunya) - Valldaura Labs Group, accountable for the cooperation between IAAC and BSC in developing a research project on Urban Simulation Models. She is now a PhD candidate at BSC and UIC (Universitat Internacional de Catalunya). Her doctoral research focuses on the crucial role of big data in urban planning and management and on their potential use for decision-making process and exploratory purpose.