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A macro-scale model of co-evolution for cities and transportation networks

Abstract

The complexity of Urban Systems is closely linked to the co-evolutive character of their different components or agents (Pumain, 1997). In the case of cities and transportation networks, this co-evolution has been shown empirically (Bretagnolle, 2009) but remains poorly understood in terms of its dynamical processes. We introduce a model of spatial interactions between cities at the macro-scale, in the spirit of stochastic urban growth models inheriting from the Gibrat model (Favaro and Pumain, 2011). We include evolving transportation networks, in order to explore stylized hypothesis on the interactions and drivers of the growth of both network and cities. In a multi-modeling fashion, the model can take into account various processes such as between cities direct interactions, network-mediated interactions, feedback of network flows, and for the network demand-induced growth. The latter is tested at different abstraction levels that are the time-distance matrix between cities, and physical network growth trying to satisfy greedy time-gain optimization criteria. We use as a benchmark network the geographical shortest paths that have been shown in a previous work to already capture network effects (Raimbault, 2016). The model is tested and explored on synthetic city systems, generated following a simple heuristic to follow the rank-size law and Central Place Theory. The systematic exploration through intensive computation unveils different interaction regimes across the parameter space. In some, the introduction of the network can drastically change the fate of some cities, whereas the top-distribution hierarchy is reinforced, what is consistent with empirical observations in the literature. Some regimes actually exhibit circular causalities between network and city growth, corresponding to the intricate co-evolution. The model will be applied to the French Urban System on long time dynamical data (Pumain-INED database for populations spanning between 1831 and 1999, with the evolving railway network from 1850 to 2000, and a specifically-designed database of the highway networks containing its full genesis from 1950 to 2015), and to the Chinese Urban System after 2000 with the High Speed Rail (HSR) network, both realized and planned. Expected results concern both accurate city population growth reproduction, and network patterns, i.e. how does taking into account dynamical networks can introduce further exploratory power in such models, and reciprocally how can such coupled models produce realistic networks compared to more classical autonomous models of network growth. The role of medium-sized cities on the trajectories of the system can also be examined with the model. Finally, a comparison between the urban systems in different geographical and political contexts and at different scales should unveil implications of planning on the interactions between networks and cities, for example by comparing the rather bottom-up growth of the French railway network to the top-down state-planned French highway and Chinese HSR networks.

Biography

Juste Raimbault is a PhD candidate in geography at UMR Géographie-cités. Trained as an engineer at Ecole Polytechnique and at Ecole Nationale des Ponts et Chaussées with a specialty in urban systems (City, Environment, Transportation), he also holds a Msc in Complex Systems Science from Ecole Polytechnique. This multidisciplinary formation is due to and the source of broad research interests linked to the application of Complex Systems methods to the study of urban systems. His thesis is focused on the study of Interactions between Networks and Territories, questioning in particular the construction of models for the co-evolution of land-use and transportation systems, and an associated geographical theory of co-evolutive networked territorial systems. Implications and applications range at various scales from e.g. the modeling of urban growth to the empirical study of transportation systems. His work in China is aimed to collect empirical field support for the application of models: one at the meso-scale including decision making processes for transportation planning, applied on Guangzhou Mega-city Region, with a focus on the role of Zhuhai on regional development; the other at the macro-scale as a model of growth for Chinese cities, interrogating in particular the influence of medium-sized cities on global dynamics. He also currently works on interdisciplinary collaborations from a Complex Systems Science perspective (in very different fields such as Ecology, Evidence-based Economics, Quantitative Finance, Urbanism, Epistemology).