A simple model of urban evolution based on innovation diffusion

Juste Raimbault[1,2,3]

[1]Center for Advanced Spatial Analysis, University College London
[2]UPS CNRS 3611 ISC-PIF
[3]UMR CNRS 8504 Géographie-cités
juste.raimbault@polytechnique.edu

Abstract

Introduction

Urban systems Batty and Marshall (2009)

Eletreby et al. (2020) diffusion/evolving

Votsis and Haavisto (2019) use the concept of Urban DNA to characterize morphological properties of cities such as density or the role of the road network. Similarly, Kaya and Bölen (2017) describe cities based on their morphological properties

Wu and Silva (2011)

Urban evolution model

Rationale

The principal idea in the model is to build on a concept of "Urban DNA" which would capture evolution processes as in biological evolution and cultural evolution, i.e. a kind of genome that cities would be exchanging and which would undergo mutation processes. A suitable candidate is to build on the concept of *meme* introduced in the field of cultural evolution. However, several particularities must be stressed out when working with urban systems.

D'Acci (2014)

Batty (2009)

Blommestein and Nijkamp (1987) describes a model of innovation diffusion and urban dynamics with endogenous demand for innovations, but in which the spatial component only influences prices of innovations.

Deffuant et al. (2005) give an example of an elaborated model for adoption dynamics at the microscopic level.

Effective channels for the diffusion of innovations are multiple, and can for example be urban firm linkages (Rozenblat and Pumain, 2007).

Model description

Our model is inspired from the urban dynamics model of Favaro and Pumain (2011).

Model dynamics Innovation occur along dimensions $1 \leq d \leq D$, and are indexed by their order of apparition c.

The crossover between urban genomes relies on spatial processes of innovation diffusion, following a spatial interaction model given by

$$\delta_{c,i,t} = \frac{\sum_j p_{c,j,t-1}^{s_c} \exp\left(-\lambda_s d_{ij}\right)}{\sum_c \sum_j p_{c,j,t-1}^{s_c} \exp\left(-\lambda_s d_{ij}\right)}$$

The sizes of cities evolve according to their performance in terms of innovation, i.e. more innovative cities are more attractive, with $G_{ij} = w_G \cdot \frac{V_{ij}}{<V_{ij}>}$ such that

$$V_{ij} = \frac{p_i p_j}{\left(\sum_k p_k\right)^2} \exp\left(-\lambda_m d_{ij} \prod_c \delta_{c,i}^{\phi_c}\right)$$

with $\phi_c = \sum_i p_{i,c} / \sum_{i,c} p_{i,c}$

Mutation corresponds to the introduction of new innovations with utility $s_{c+1} = g_0 \cdot s_c$ in a randomly chosen city with a hierarchy parameter α_I, if global adoption share ϕ_c is larger than a threshold θ_I. Initial utility s_0 is a parameter. New innovation has an initial penetration rate r_I in the city.

Synthetic setup

Indicators

Results

Discussion

References

Batty, M. (2009). A digital breeder for designing cities. *Architectural Design*, 79(4):46–49.

Batty, M. and Marshall, S. (2009). Centenary paper: The evolution of cities: Geddes, abercrombie and the new physicalism. *Town Planning Review*, 80(6):551–574.

Blommestein, H. and Nijkamp, P. (1987). Adoption and diffusion of innovations and the evolution of spatial systems. In *Economic Evolution and Structural Adjustment*, pages 368–380. Springer.

D'Acci, L. (2014). Urban dna for cities evolutions. cities as physical expression of dynamic equilibriums between competitive and cooperative forces. *arXiv preprint arXiv:1408.2874*.

Deffuant, G., Huet, S., and Amblard, F. (2005). An individual-based model of innovation diffusion mixing social value and individual benefit. *American Journal of Sociology*, 110(4):1041–1069.

Eletreby, R., Zhuang, Y., Carley, K. M., Yağan, O., and Poor, H. V. (2020). The effects of evolutionary adaptations on spreading processes in complex networks. *Proceedings of the National Academy of Sciences*, 117(11):5664–5670.

Favaro, J.-M. and Pumain, D. (2011). Gibrat revisited: An urban growth model incorporating spatial interaction and innovation cycles. : Ł. *Geographical Analysis*, 43(3):261–286.

Kaya, H. S. and Bölen, F. (2017). Urban dna: morphogenetic analysis of urban pattern.

Rozenblat, C. and Pumain, D. (2007). Firm linkages, innovation and the evolution of urban systems. *Cities in globalization: Practices, policies, theories*, pages 130–156.

Votsis, A. and Haavisto, R. (2019). Urban dna and sustainable cities: A multi-city comparison. *Frontiers in Environmental Science*, 7:4.

Wu, N. and Silva, E. A. (2011). Urban dna: exploring the biological metaphor of urban evolution with dg-abc model. In *Proceedings The 14th AGILE International Conference on Geographic Information Science. Utrecht University*.