Morphogenesis, Evolution and Co-evolution of Cities

J. Raimbault[1,2,3]

[1] CASA, UCL; [2] UPS CNRS 3611 ISC-PIF; [3] UMR CNRS 8504 Géographie-cités

Context

- Urban complexity and interdisciplinarity [Pumain, 2005]
- Urban science and Artificial Life: applications of biological concepts in planning and design [Batty and Marshall, 2009]

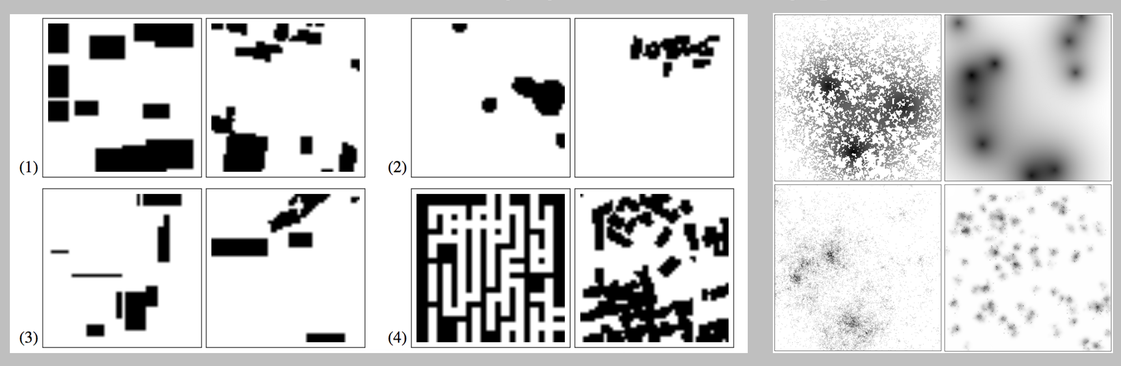
→ *Urban morphogenesis, urban evolution and urban co-evolution as concepts to understand urban dynamics and sustainability*

Urban morphogenesis

Definition of urban morphogenesis [Raimbault, 2018b]: *strong coupling between the dynamics of urban form and function*

Generative models for urban morphogenesis:

- cellular automaton and road network [Raimbault et al., 2014]
- building configurations [Raimbault and Perret, 2019]
- reaction-diffusion model for population density [Raimbault, 2018a]



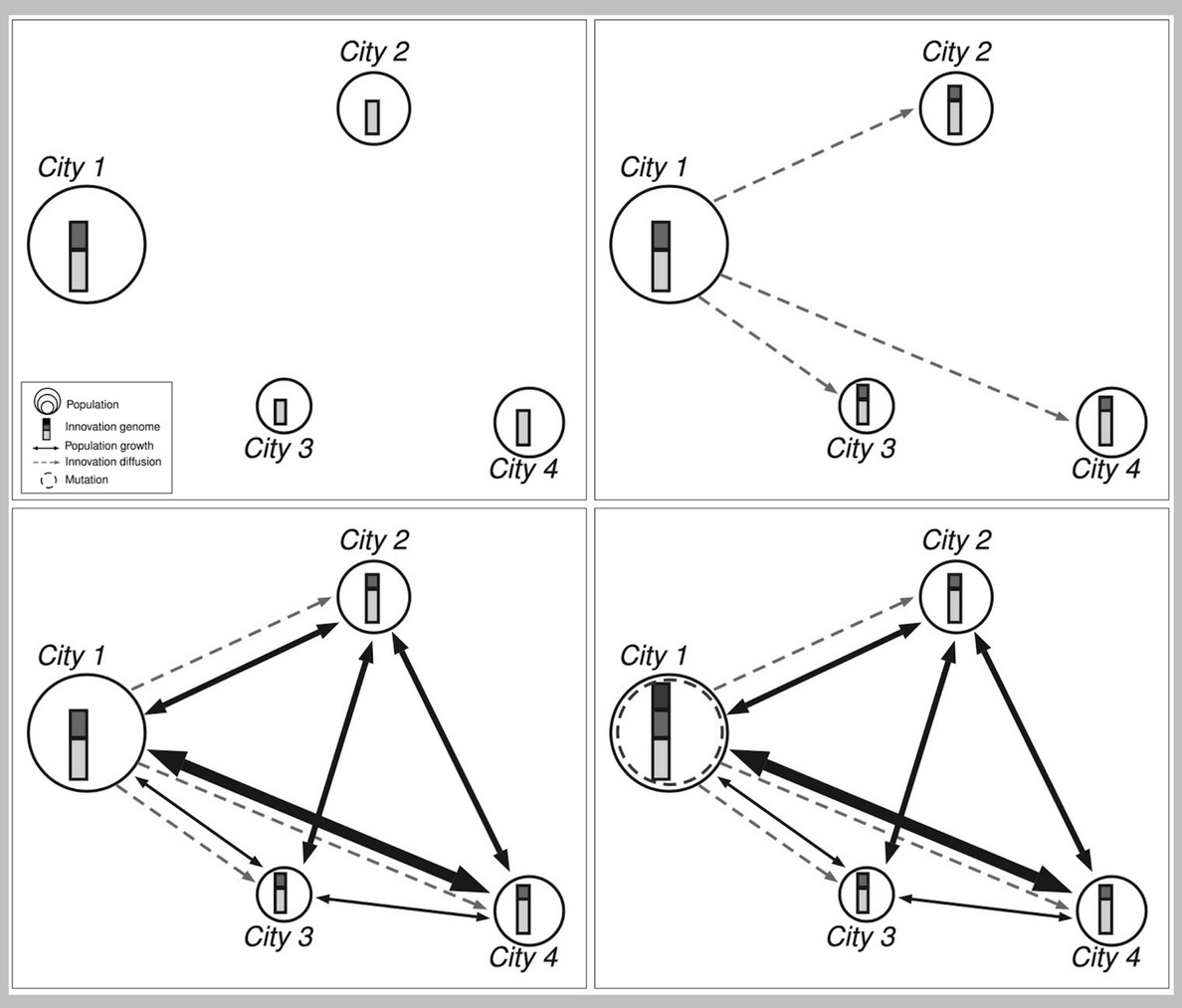
Left: buildings [Raimbault and Perret, 2019]; Right: population [Raimbault, 2020a]

Urban evolution

Urban evolutionary theory introduced by [Pumain, 1997]

An **explicit urban evolution model** described by [Raimbault, 2020b]:

- Spatial diffusion of innovations captures transmission processes
- Spatial interaction models drive innovation and population growth
- Urban genome as the distribution of different innovations
- Mutation as the emergence of new innovations

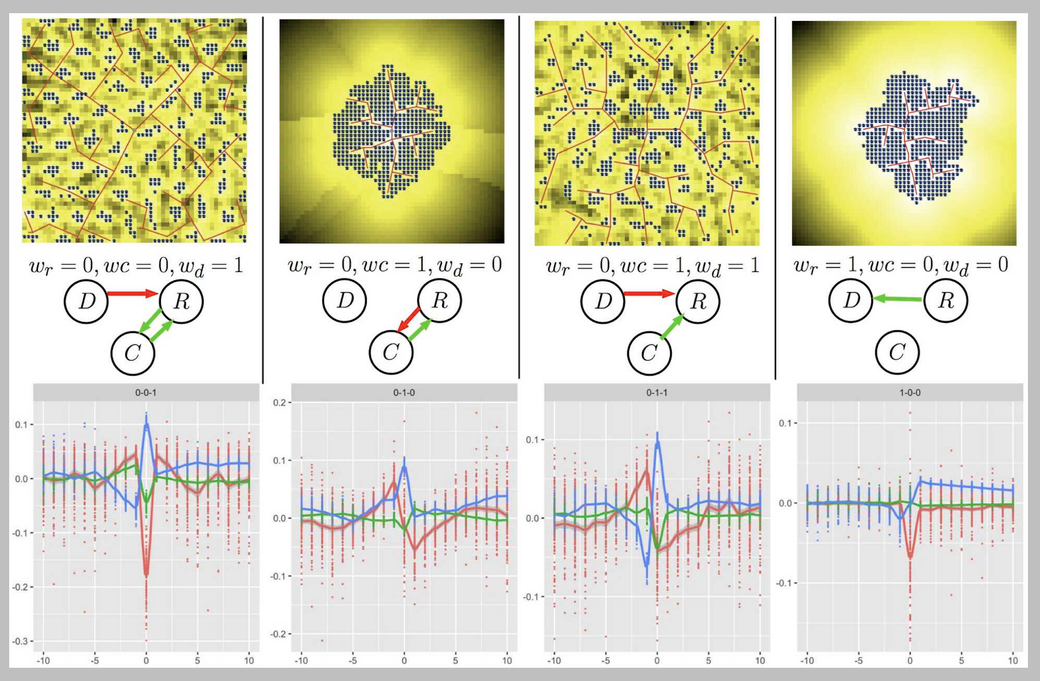


Processes in the urban evolution model [Raimbault and Pumain, 2020]

Co-evolution in urban systems

Definition of urban co-evolution [Raimbault, 2018b]: *statistically co-evolving population of urban entities within territorial niches*

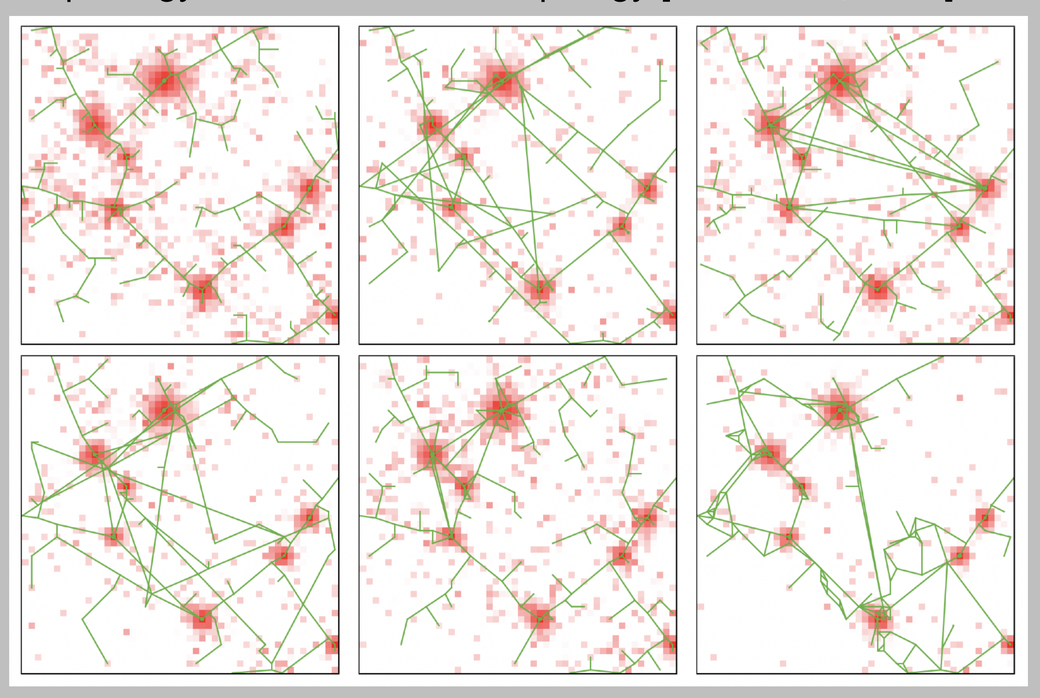
Characterisation method based on circular Granger causalities between proxy variables



Diverse causality regimes in a morphogenesis model [Raimbault, 2017]

Application to transportation networks and territories:

- At the **mesoscopic** scale (urban areas), co-evolution of urban morphology and road network topology [Raimbault, 2019]



Multiple network growth heuristics [Raimbault, 2018c]

- Land-use transport model and transportation governance at the **urban region** scale [Raimbault and Le Néchet, 2021]
- At the **macroscopic** scale (systems of cities), co-evolution between cities and inter-city transport networks [Raimbault, 2021]

Possible extensions: application to other urban dimensions (mobility and accessibility e.g.), integration with explicit urban evolution models

Discussion

- Potential transfer of other concepts to urban systems: biomimicry, autopoiesis, collective computation
- Towards multi-scale models for urban systems
- Application to sustainable policies at multiple spatial and time scales [Rozenblat and Pumain, 2018]

References

Batty, M. and Marshall, S. (2009).
Centenary paper: The evolution of cities: Geddes, abercrombie and the new physicalism.
Town Planning Review, 80(6):551–575.

Pumain, D. (1997).
Pour une théorie évolutive des villes.
L'Espace géographique, pages 119–134.

Pumain, D. (2005).
Cumulativité des connaissances.
Revue européenne des sciences sociales. European Journal of Social Sciences, (XLIII-131):5–12.

Raimbault, J. (2017).
Identification de causalités dans des données spatio-temporelles.
In *Spatial Analysis and GEOmatics 2017*.

Raimbault, J. (2018a).
Calibration of a density-based model of urban morphogenesis.
PloS one, 13(9):e0203516.

Raimbault, J. (2018b).
Caractérisation et modélisation de la co-évolution des réseaux de transport et des territoires.
PhD thesis, Université Paris 7 Denis Diderot.

Raimbault, J. (2018c).
Multi-modeling the morphogenesis of transportation networks.
In *Artificial Life Conference Proceedings*, pages 382–383. MIT Press.

Raimbault, J. (2019).
An urban morphogenesis model capturing interactions between networks and territories.
In *The mathematics of urban morphology*, pages 383–409. Springer.

Raimbault, J. (2020a).
A comparison of simple models for urban morphogenesis.
arXiv preprint arXiv:2008.13277.

Raimbault, J. (2020b).
A model of urban evolution based on innovation diffusion.
In *Artificial Life Conference Proceedings*, pages 500–508. MIT Press.

Raimbault, J. (2021).
Modeling the co-evolution of cities and networks.
In *Handbook of Cities and Networks*. Edward Elgar Publishing.

Raimbault, J., Banos, A., and Doursat, R. (2014).
A hybrid network/grid model of urban morphogenesis and optimization.
In *4th International Conference on Complex Systems and Applications*, pages 51–60.

Raimbault, J. and Le Néchet, F. (2021).
Introducing endogenous transport provision in a luti model to explore polycentric governance systems.
Journal of Transport Geography, 94:103115.

Raimbault, J. and Perret, J. (2019).
Generating urban morphologies at large scales.
In *Artificial Life Conference Proceedings*, pages 179–186. MIT Press.

Raimbault, J. and Pumain, D. (2020).
Spatial dynamics of complex urban systems within an evolutionary theory frame.
arXiv preprint arXiv:2010.14890.

Rozenblat, C. and Pumain, D. (2018).
Conclusion: Toward a methodology for multi-scalar urban system policies.

International and Transnational Perspectives on Urban Systems, page 385.

juste.raimbault@polytechnique.edu