

Multiscalar models for systems of cities

J. Raimbault^{1,2,3,4,*}

* `juste.raimbault@ign.fr`

¹ LASTIG, IGN-ENSG

²CASA, UCL

³UPS CNRS 3611 ISC-PIF

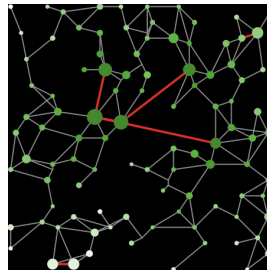
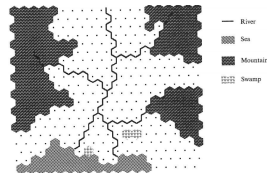
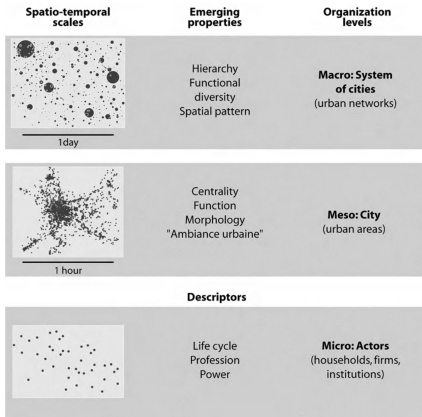
⁴UMR CNRS 8504 Géographie-cités

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Session Theoretical Geography 1

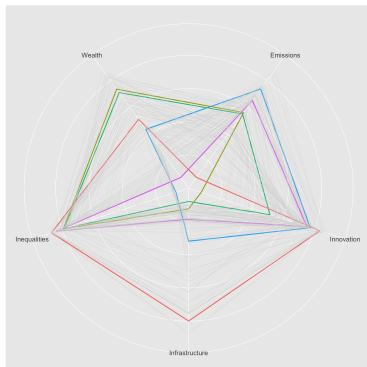
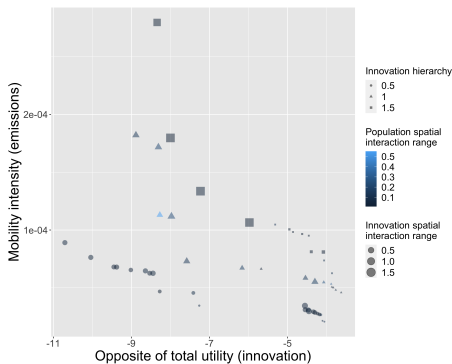
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An evolutionary theory for urban systems



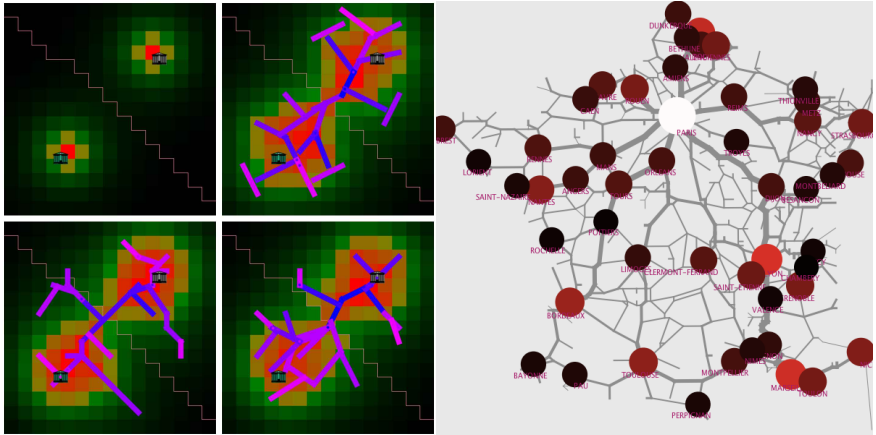
An evolutionary urban theory considering cities as systems within systems of cities [Pumain, 2018]; Simpop 1 model [Sanders et al., 1997]; SimpopNet model [Schmitt, 2014]

Multi-modeling urban systems dynamics for sustainability



Trade-offs between sustainable development goals in systems of cities [Raimbault et al., 2020]; multi-modeling for many-objectives SDGs optimisation [Raimbault and Pumain, 2022]

Hybrid models mixing scales



Simulation models for systems of cities and transportation networks making a slight bridge between scales: transportation governance modeling [Raimbault and Le Néchet, 2021]; physical network self-reinforcement [Raimbault, 2020a]

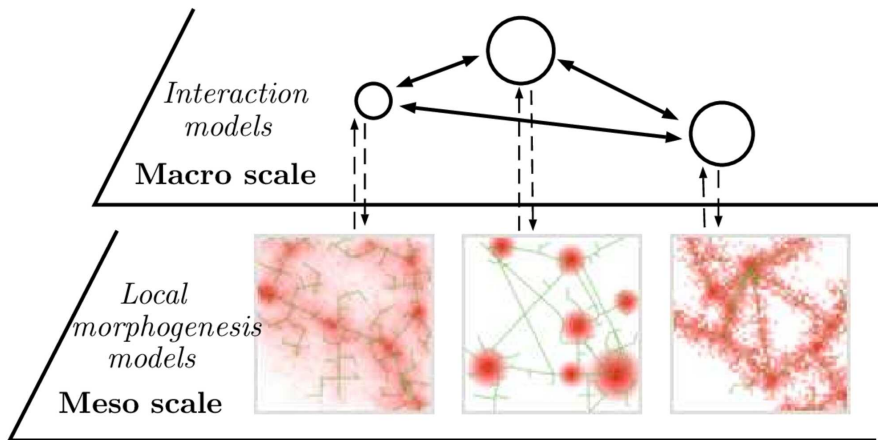
Towards multiscale models

→ multi-scale simulation models are needed to explore sustainable policies [Rozenblat and Pumain, 2018]

→ multi-scale urban models remain however underexplored in the literature

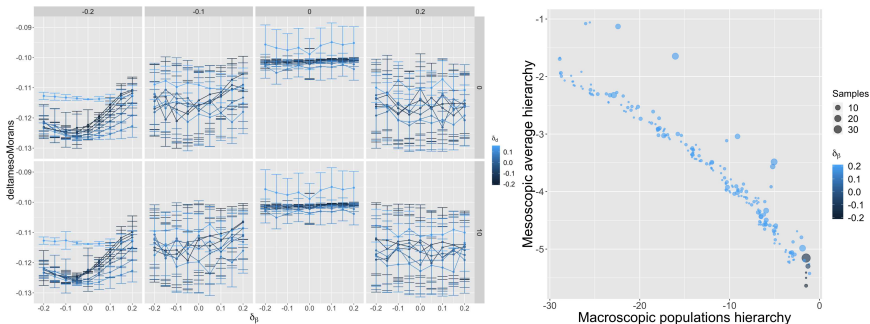
This contribution: *to synthesise lessons from two different recent tentatives to build multi-scale urban models with a strong coupling between scales: an urban morphogenesis model [Raimbault, 2021] and an innovation diffusion model [Raimbault and Pumain, 2023], learnt from the systematic exploration of these models using OpenMOLE [Reuillon et al., 2013]*

Urban morphology and inter-city interactions



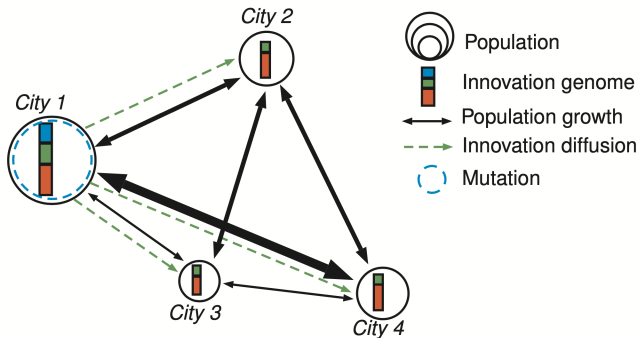
A strong coupling explored by [Raimbault, 2021] between urban morphogenesis aggregation-diffusion processes at the meso scale [Raimbault, 2018] and interactions between cities at the macro scale [Raimbault, 2020b]

Model exploration



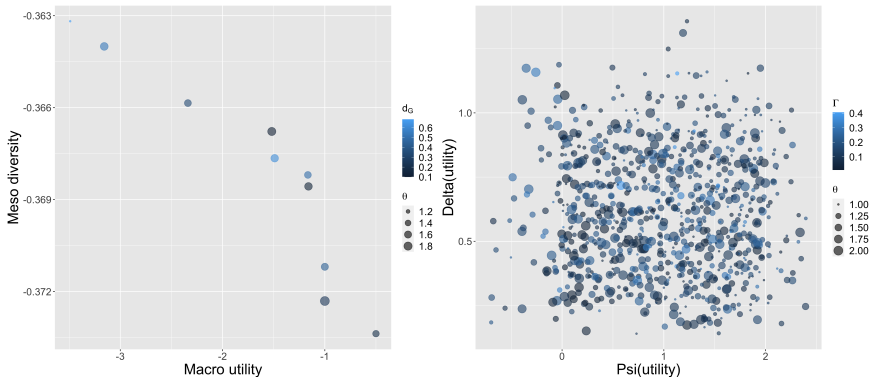
(Left) Non-monotonous effect of policy parameters linking scales; (Right) Bi-objective optimisation of contradictory objectives across scales

Multi-scale innovation dynamics



A bi-scale model explored by [Raimbault and Pumain, 2023], coupling urban evolution based on innovation diffusion at the macro scale [Raimbault, 2020c], with intra-urban innovation cluster dynamics between firms for the emergence of new innovations [Raimbault, 2022]; quantification of strong emergence using indicators by [Rosas et al., 2020]

Model exploration



(Left) bi-optimisation between contradictory objectives across scales;
(Right) diversity of emergence regimes obtained with a diversity search algorithm

Common aspects from simulation results

- strong emergence quantified in a high diversity of regimes for the innovation diffusion model, probable (given cross-scale parameter influence, but not quantified) for the urban morphogenesis model
- optimisation objectives across scales seem generally contradictory, and can be simultaneously optimised with Pareto trade-offs

Teaching 1: ontologies and feedbacks

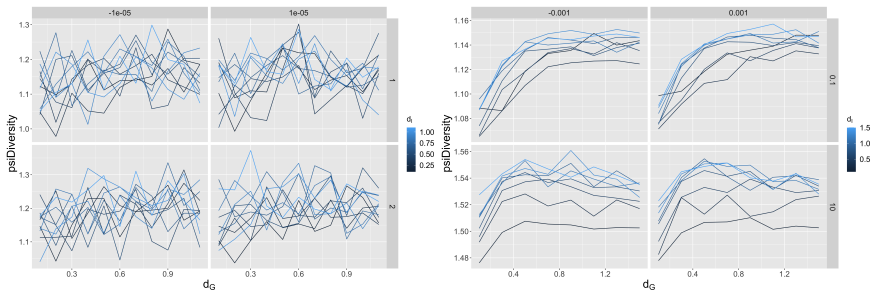
- models coupling scales with a single direction of inter-scale feedback can be simplified to non-stationary dynamics or fixed effects at a single scale: “strong” coupling is necessary
- scales have their own distinct ontologies with their own processes
- inter-scales processes may be necessary to capture feedbacks and may necessitate their own ontology

Teaching 2: consistent data parametrisation

→ model parametrisation with real data is more complicated: which scales? need of consistent datasets in case of multiple scales (cf Geodivercity project); how to consistently setup model states? ...

→ synthetic systems of cities are a first way to explore model dynamics independently of geographical contingencies [Raimbault et al., 2019]

Teaching 3: stochasticity



→ statistical convergence of indicators is more difficult to reach (example above for innovation diffusion: 20 vs 10,000 replications, despite “good-looking” empirical Sharpe ratios suggesting a low number of repetitions)

→ non-linearities, fat-tail distribution, noise propagation between scales?
More uncertainty-based/Bayesian validation methods?

Teaching 4: quantifying strong emergence

- issue of over-complication/overfitting (generic issue for simulation models [Raimbault, 2020b]): is the multi-scale aspect necessary?
- the stronger the emergence, the more it is needed? [Bedau, 2002]: for nominal emergence, can be simplified/surrogated; for weak emergence, depends on the cases? (cf Schelling model); for strong emergence difficult to be avoided because of the autonomy?
- need indicators and methods to systematically quantify emergence in multi-scalar simulated dynamics: cf. information-theory-based indicators proposed by [Rosas et al., 2020]
- link between strength of emergence and strength of coupling, and other types of complexities (such as [Pumain, 2003]’s “interdisciplinary” complexity), seems to be an open question, related to the nature of complexities [Raimbault, 2020d] and complex knowledge/knowledge of the complex

Discussion: still a long way to go!

→ there seem to be methodological regularities when building strongly coupled multi-scale models - to what extent do they depend on the type of system, methodological framework, do they hold with a parametrisation on real data?

→ subtle compromise between model complication/complexity and the effective capture of multi-scale dynamics

→ application to multi-scalar policies still far, but already possible in a stylised way such as for trade-offs between SDGs (at a single scale for now [Raimbault and Pumain, 2022])

Open repositories for presented models:

<https://github.com/JusteRaimbault/UrbanGrowth>

<https://github.com/JusteRaimbault/InnovationMultiscale-model>



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