

Urban Morphogenesis and the co-evolution of Transportation Networks and Territories

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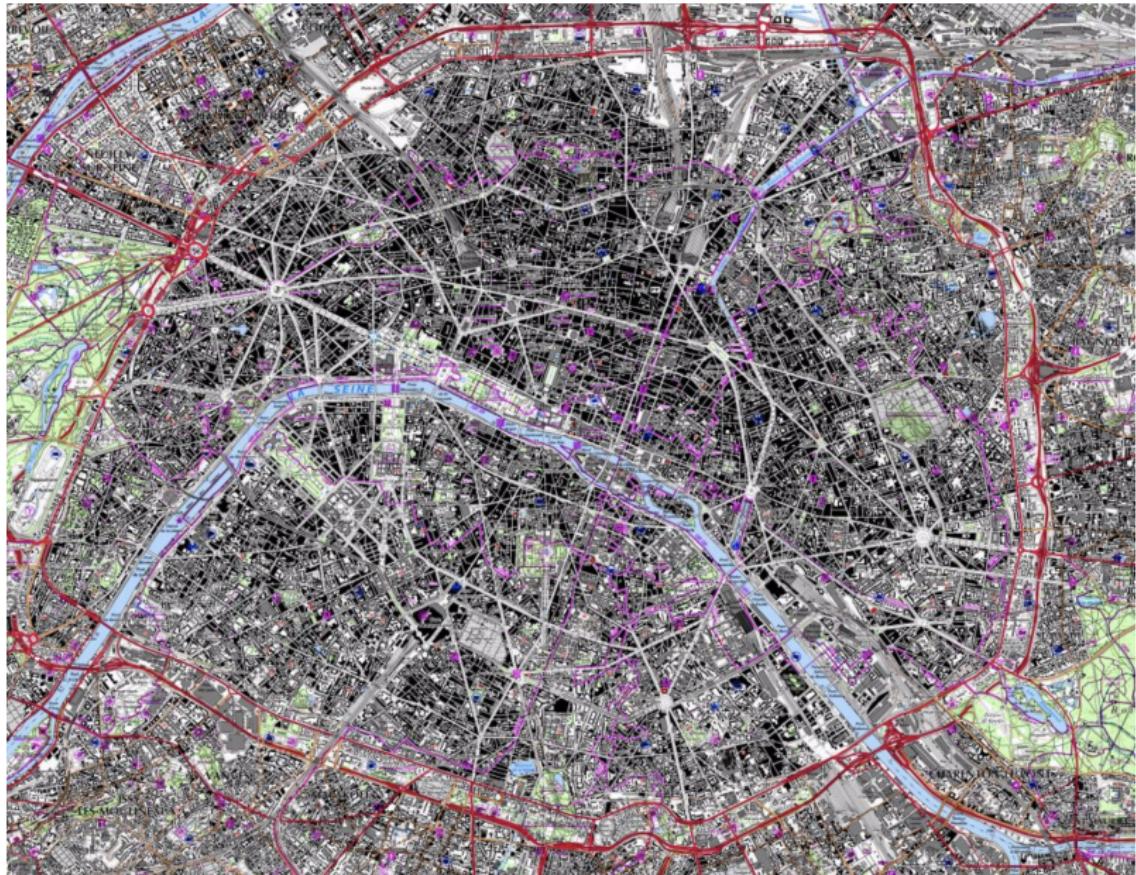
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Séminaire Equipe Paris

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Complex processes of Urban Morphogenesis



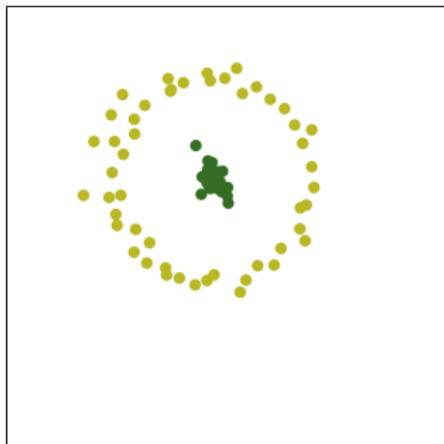
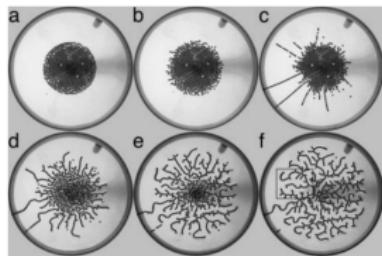
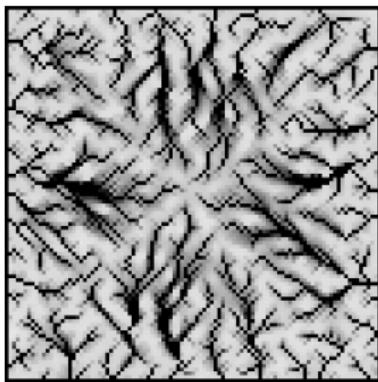
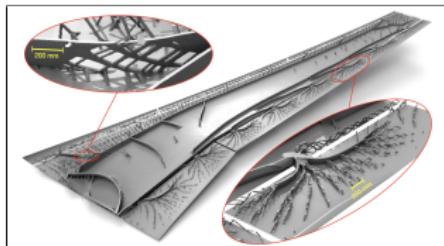
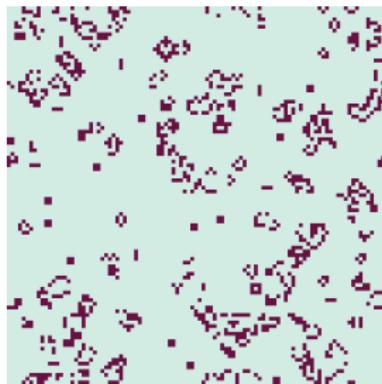
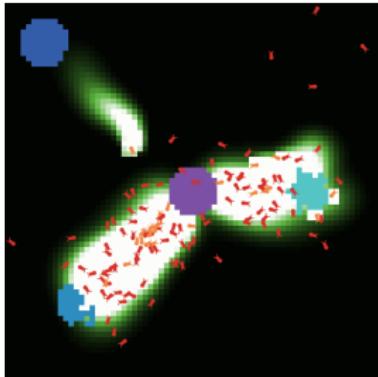
Source: Geoportal

Complex processes of Urban Morphogenesis



Source: Geoportail

What is Morphogenesis ?



Sources (in order by column). Ants, Erosion, Game of Life: NetLogo Library ; Arbotron [Jun and Hübler, 2005]; Industrial design [Aage et al., 2017]; Swarm chemistry [Sayama, 2007]

Defining Morphogenesis

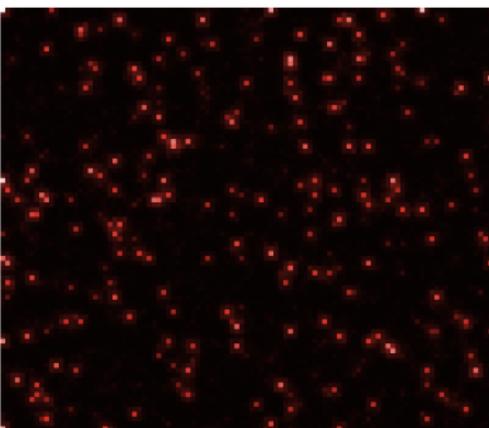
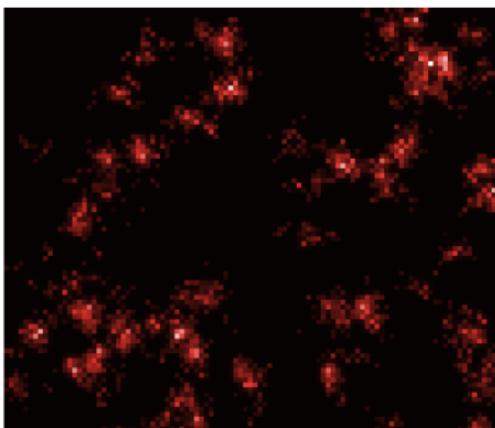
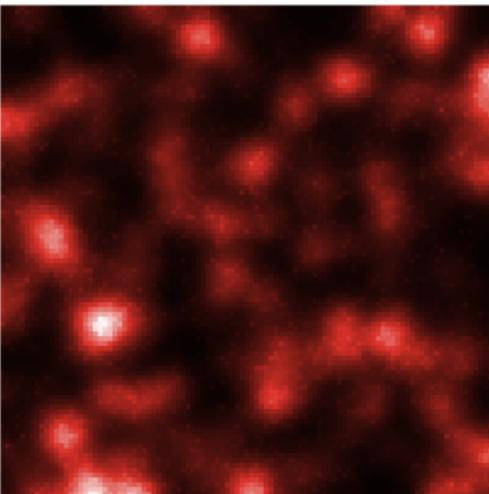
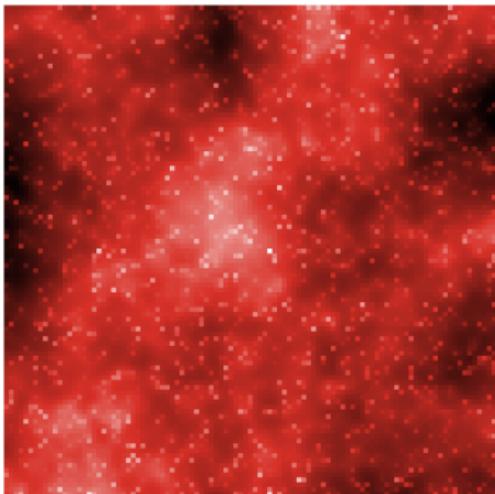
[Antelope et al., 2016]

Modeling Urban Morphogenesis

A simple Aggregation-diffusion model

Model Formalization

Generating Population Distributions



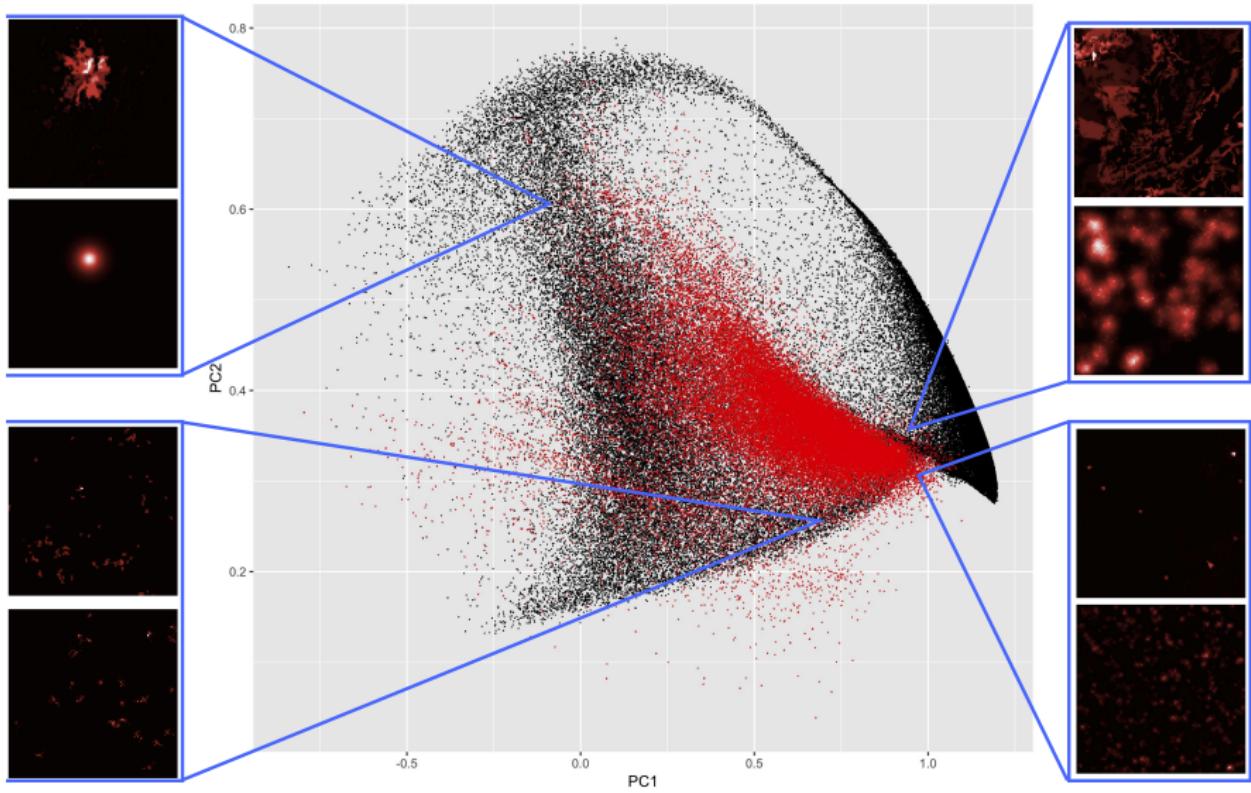
Model behavior

Model classification : PDE

Path-dependence and frozen accidents

Real Data

Model Calibration



Including more complex processes ?

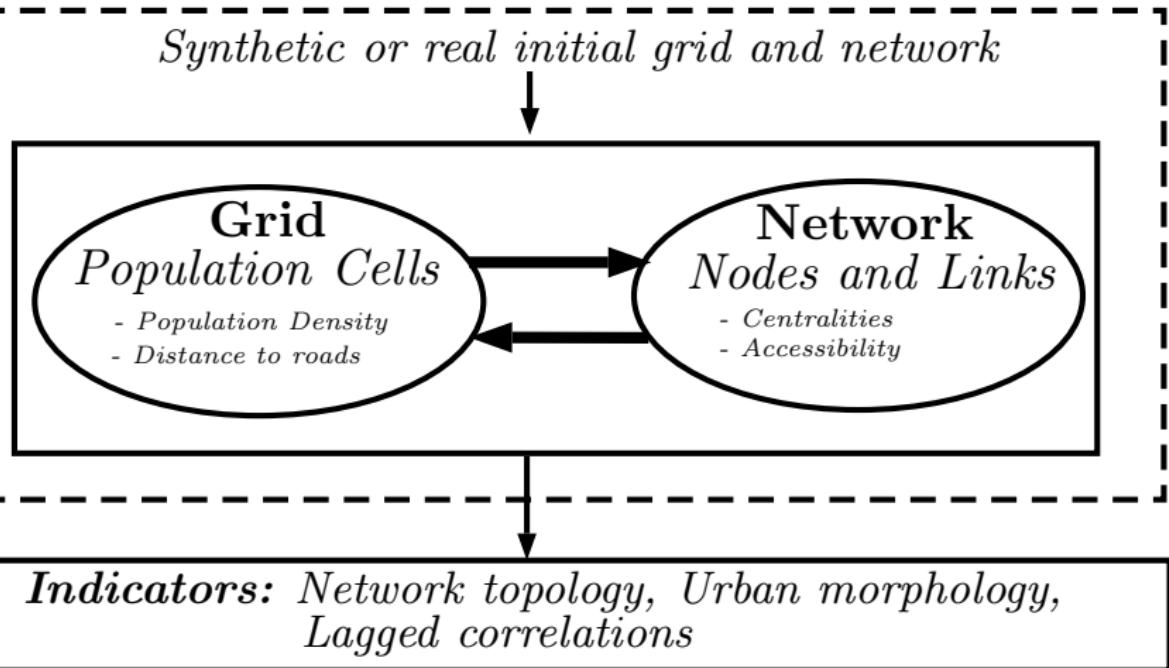
Co-evolution of Transportation Networks and Territories

A Morphogenesis Model of co-evolution

- Coupled grid population distribution and vector transportation network, following the core of [Raimbault et al., 2014]
- Local morphological and functional variables determine a patch-value, driving new population attribution through preferential attachment ; combined to population diffusion (aggregation-diffusion processes studied in [?])
- Network growth is also driven by morphological, functional and local network measures, following diverse heuristics corresponding to different processes (multi-modeling)

*Local variables and network properties induce feedback on both, thus a strong coupling capturing the **co-evolution***

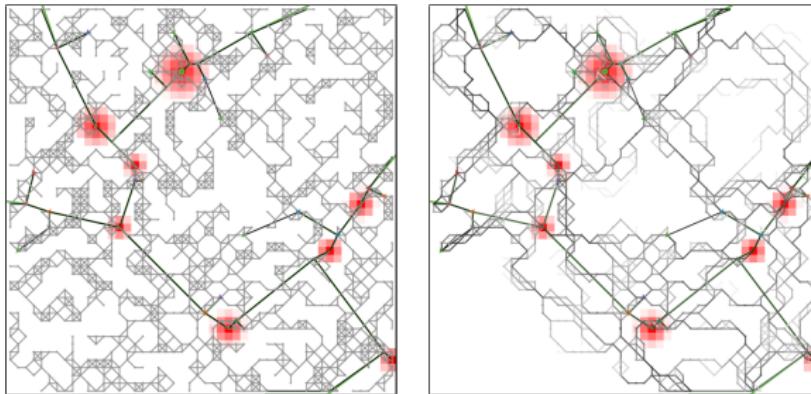
Model : Specification



Network Generation

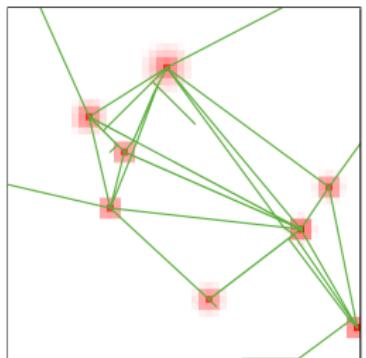
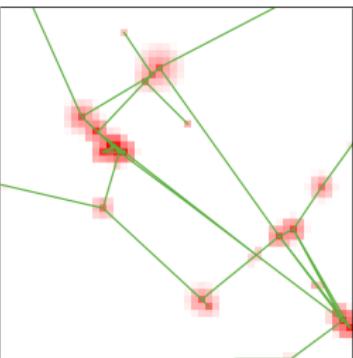
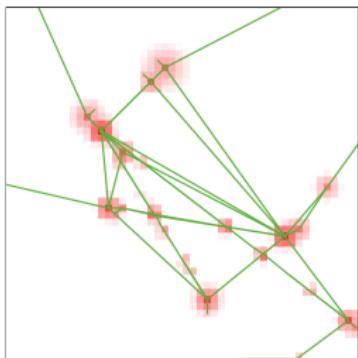
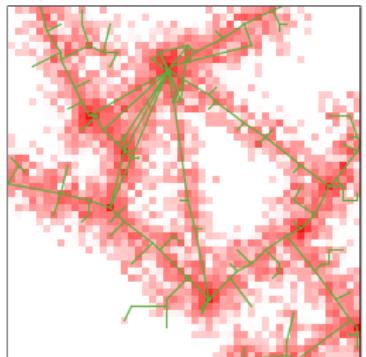
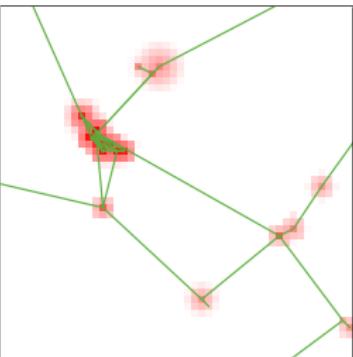
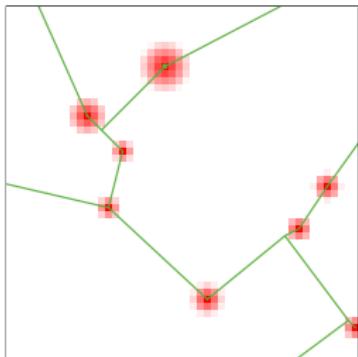
At fixed time steps :

- ① Add new nodes preferentially to new population and connect them
- ② Variable heuristic for new links, among: nothing, random, gravity-based deterministic breakdown, gravity-based random breakdown (from [Schmitt, 2014]), cost-benefits (from [Louf et al., 2013]), biological network generation (based on [Tero et al., 2010])



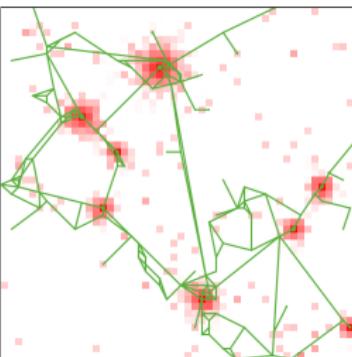
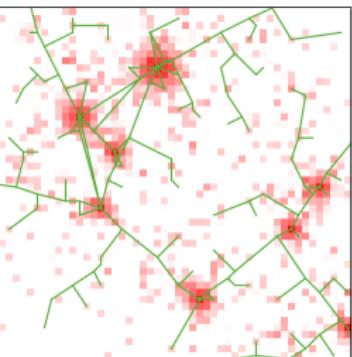
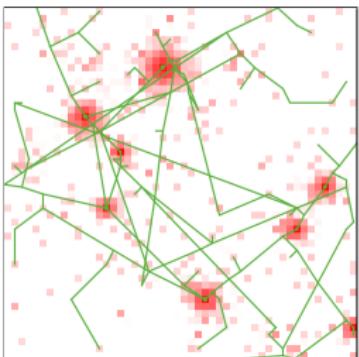
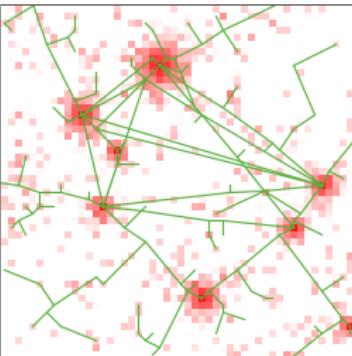
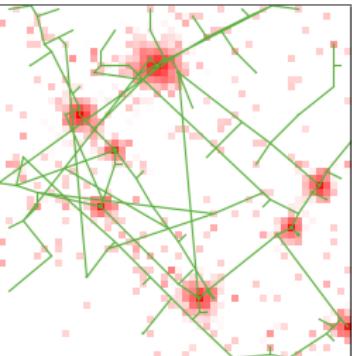
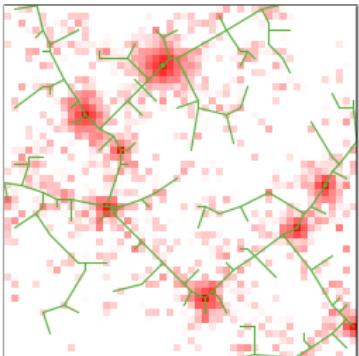
Intermediate stage for biological network generation

Generated Urban Shapes: Urban Form



In order: setup; accessibility driven; road distance driven; betweenness driven; closeness driven; population driven.

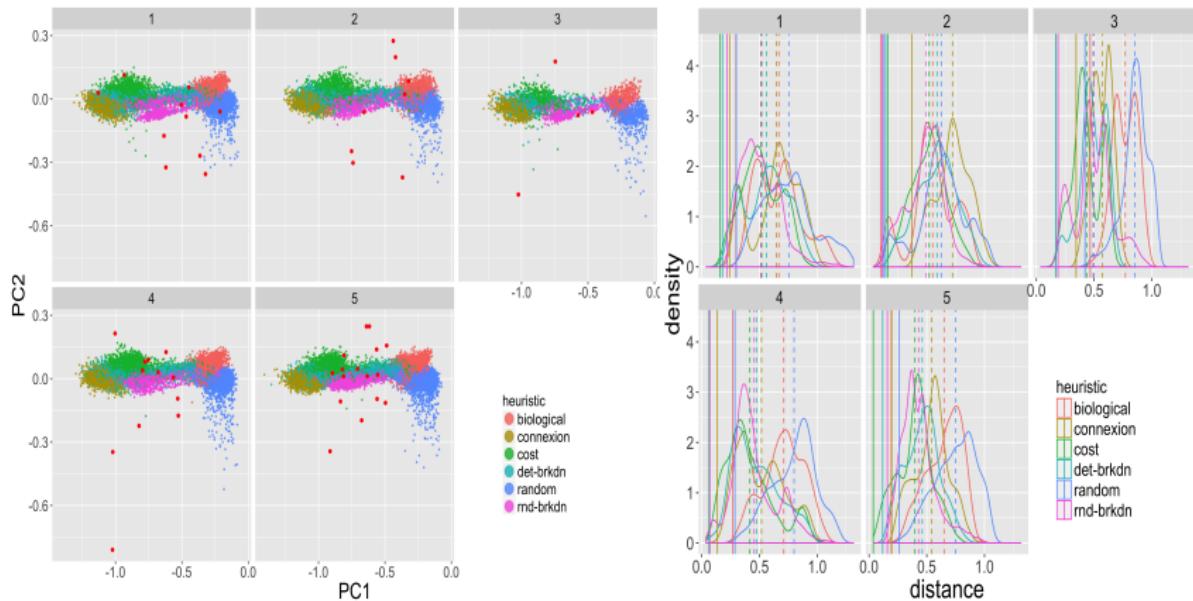
Generated Urban Shapes: Network



In order: connection; random; deterministic breakdown; random breakdown; cost-driven; biological.

Results : Network Heuristics

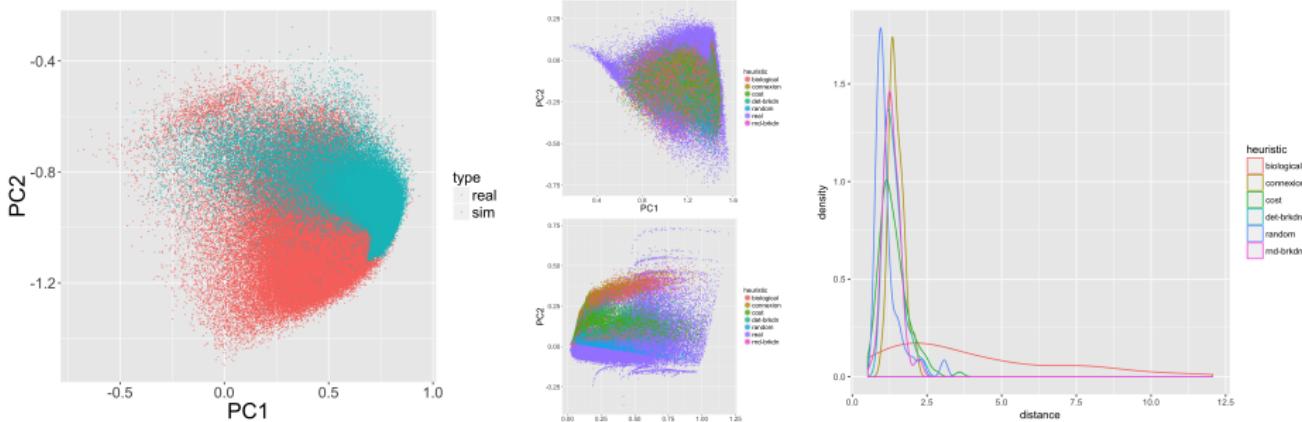
Comparison of feasible space for network indicators with fixed density



(Left) Feasible spaces by morphological class and network heuristic; (Right) Distribution of distances to topologies of real networks

Results : Calibration

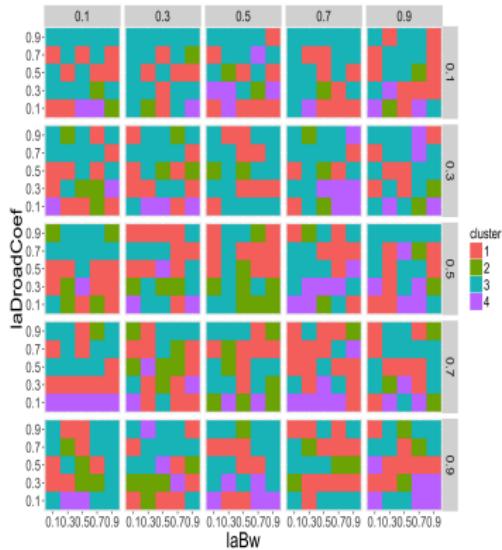
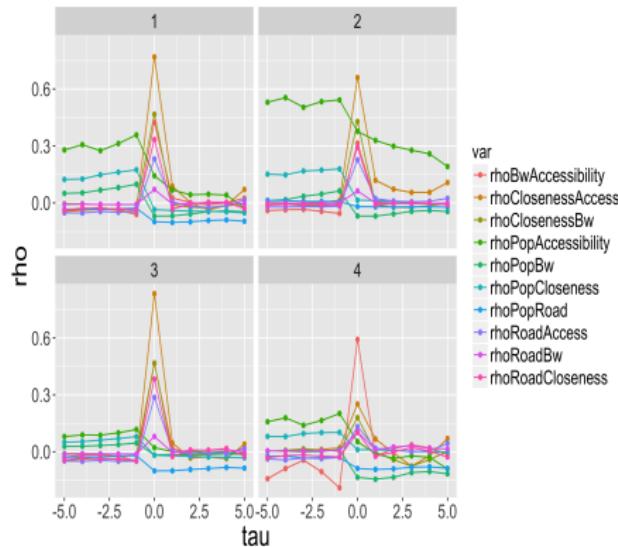
Calibration (model explored with OpenMole [Reuillon et al., 2013], $\sim 10^6$ model runs) at the first order on morphological and topological objectives, and on correlations matrices.



(Left) Full indicator space; (Middle) Morphological and Topology, by network heuristic; (Right) Distance distribution for cumulated distance for indicators and correlations.

Results : Causality Regimes

Unsupervised learning on lagged correlations between local variables unveils a diversity of causality regimes



(Left) Lagged correlation profiles of cluster centers; (Right) Distribution of regimes across parameter space

Reserve Slides

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