Multi-modeling transportation network growth

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Abstract

This research introduces a multi-modeling approach to the growth of transportation networks. More precisely, we implement and compare several models, based on biological network growth, cost-benefit rules, and gravity potential breakdown. The resulting multi-modeling framework is calibrated on observed topological data for the European road network. We show that different heuristic are complementary to cover the feasible topological space and that all are necessary to approach existing configurations, what suggests the superposition of corresponding processes in territorial systems.

The growth of transportation networks in territorial systems bears stunning similarities with biological networks, and the understanding of processes driving their spatial extension can both have practical planning applications but also bring theoretical insights into complex morphogenetic systems. Network growth models have been proposed in several disciplines (Xie and Levinson, 2009) taking into account diverse processes such as economical, geometrical, geographical processes for example. There exists to our knowledge no systematic comparison of different network generation heuristics. This research proposes such a benchmark in a multi-modeling paradigm.

Modeling network growth

We introduce a general model of road network growth, conditioned to a fixed population density, in a sequential way with the following steps. A common core ensures the positioning of new centers preferentially to population density and a direct connection to the existing network. Nodes and links are then added following different potential processes corresponding to the selected heuristic: (i) no supplementary growth (baseline); (ii) random links; (iii) biological network growth following the model of Tero et al. (2010), where new links are taken as the links with the highest capacity in the stationary flow network obtained by evolving capacities of the full network of potential new links; (iv) cost-benefit network growth as proposed by Louf et al. (2013); (v) stochastic gravity potential breakdown as used by Schmitt (2014); and (vi) a novel model based on thresholded deterministic potential breakdown. The network is grown until a fixed maximal number of new nodes to ensure comparability between the different heuristics.

A network is then quantified by topological indicators, namely average and hierarchy of closeness and betweenness centralities, diameter, efficiency and accessibility.

To compare the generated network to real data, we collected the European street network from the open data provided by OpenStreetMap, and extracted

Results

The heterogeneity of models suggested the choice of an implementation

Discussion

References

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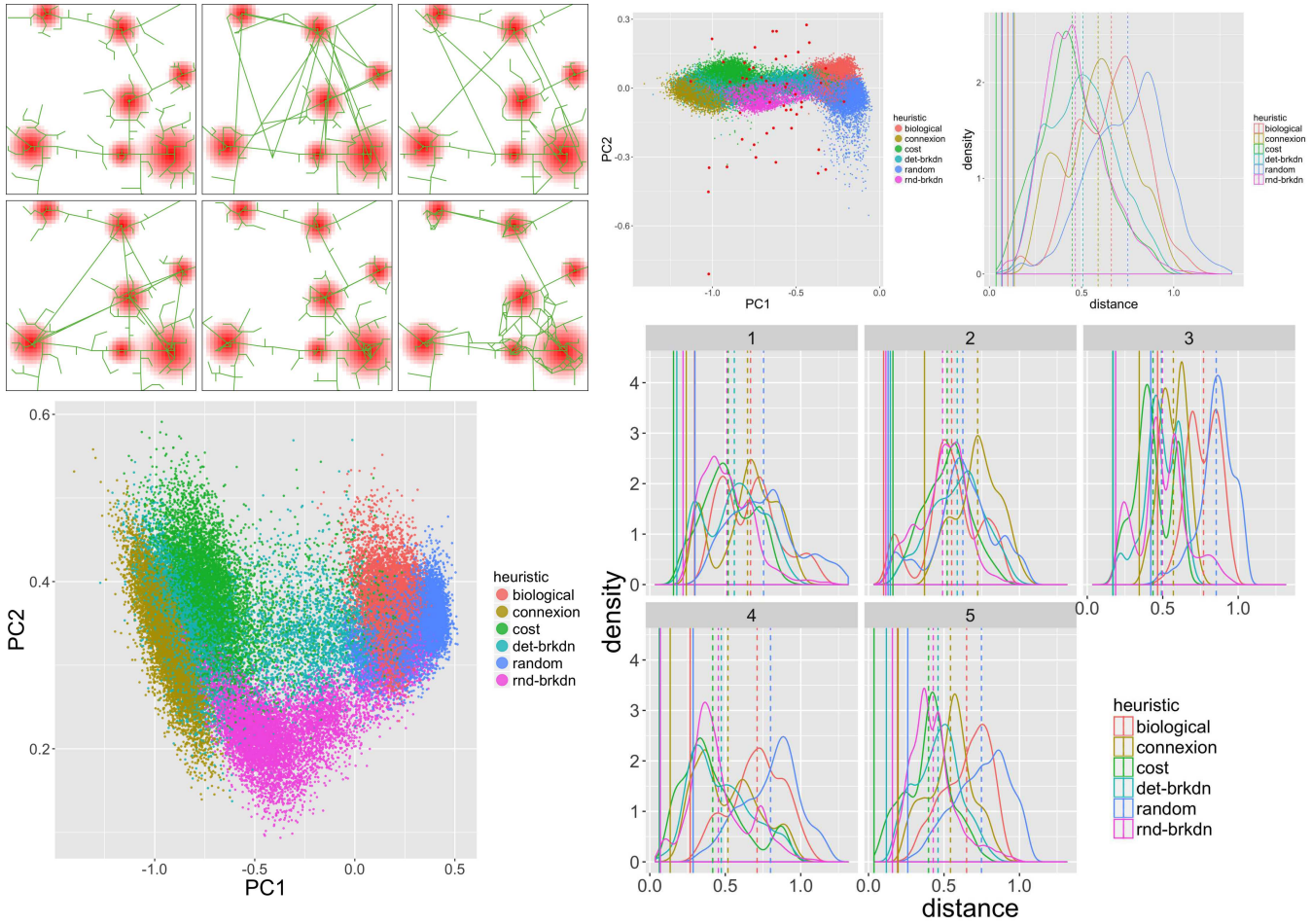

Figure 1: *(Top left)* Examples of network configuration generated by the different heuristics; *(Bottom Left)* Feasible space of topological indicators for networks generated by the model, shown in a reduced dimension after principal component analysis, with a different color for each heuristic; *(Right)* Feasible space with red points corresponding to real networks, and histograms of indicator distance to data, for all densities configuration and conditioned by the type of urban form.