Benchmarking road network growth models

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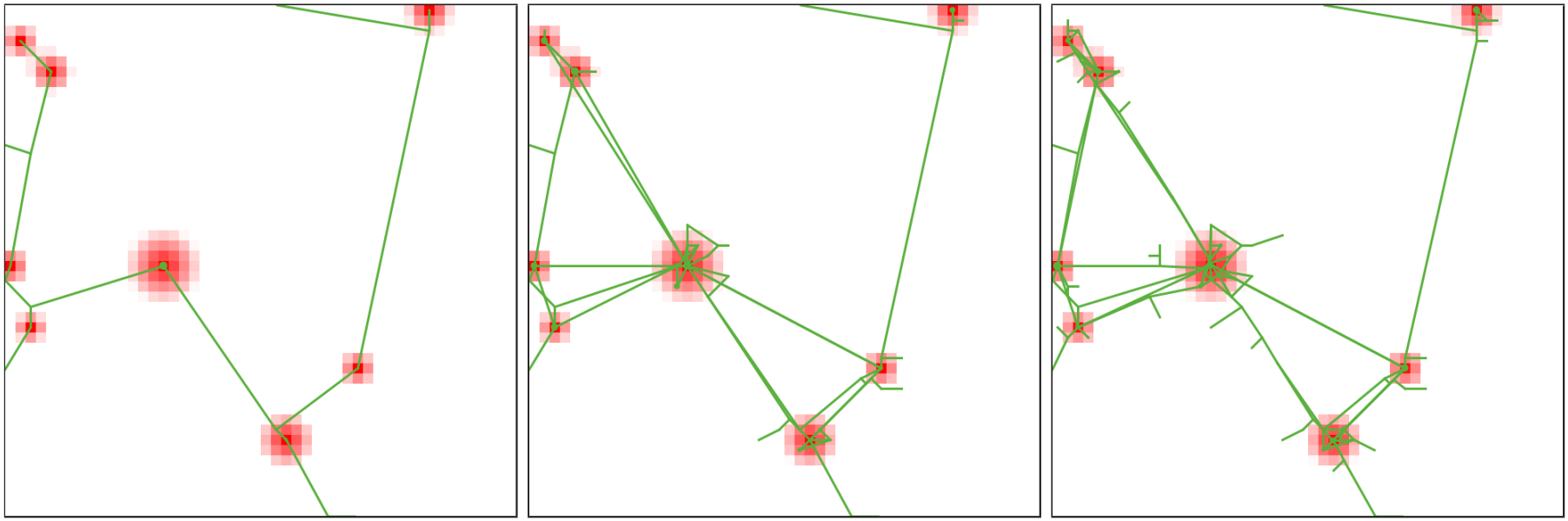
Modeling road network growth

[Cats and Birch, 2021]
[Szell et al., 2021]
[Cats et al., 2020]

Road network generation multi-model

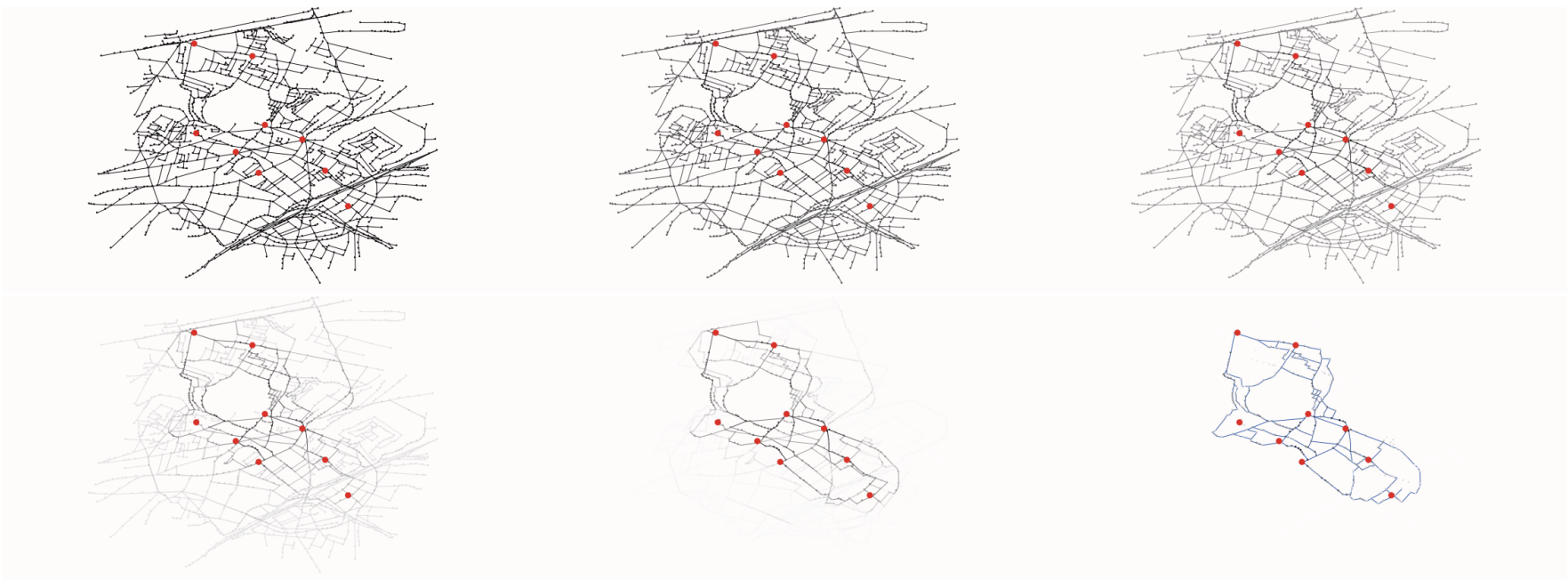
At each time step, with a fixed population density:

1. Add new nodes preferentially to 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])



Biological network generation

Model introduced by [Tero et al., 2010]: exploration and reinforcement by a slime mould searching for ressources

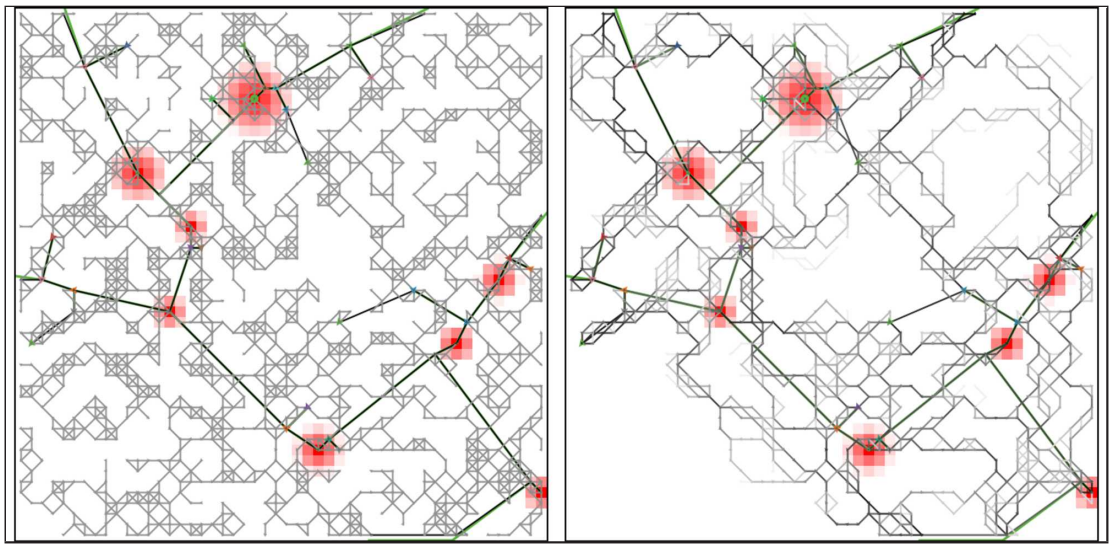


Application to the design of optimal bus routes in [Raimbault, 2018]

Biological Network generation

Adding new links with biological heuristic:

1. Create network of potential new links, with existing network and randomly sampled diagonal lattice
2. Iterate for k increasing ($k \in \{1, 2, 4\}$ in practice) :
   - Using population distribution, iterate $k \cdot n_b$ times the slime mould model to compute new link capacities
   - Delete links with capacity under θ_d
   - Keep the largest connected component
3. Planarize and simplify final network



Intermediate stage for biological network generation

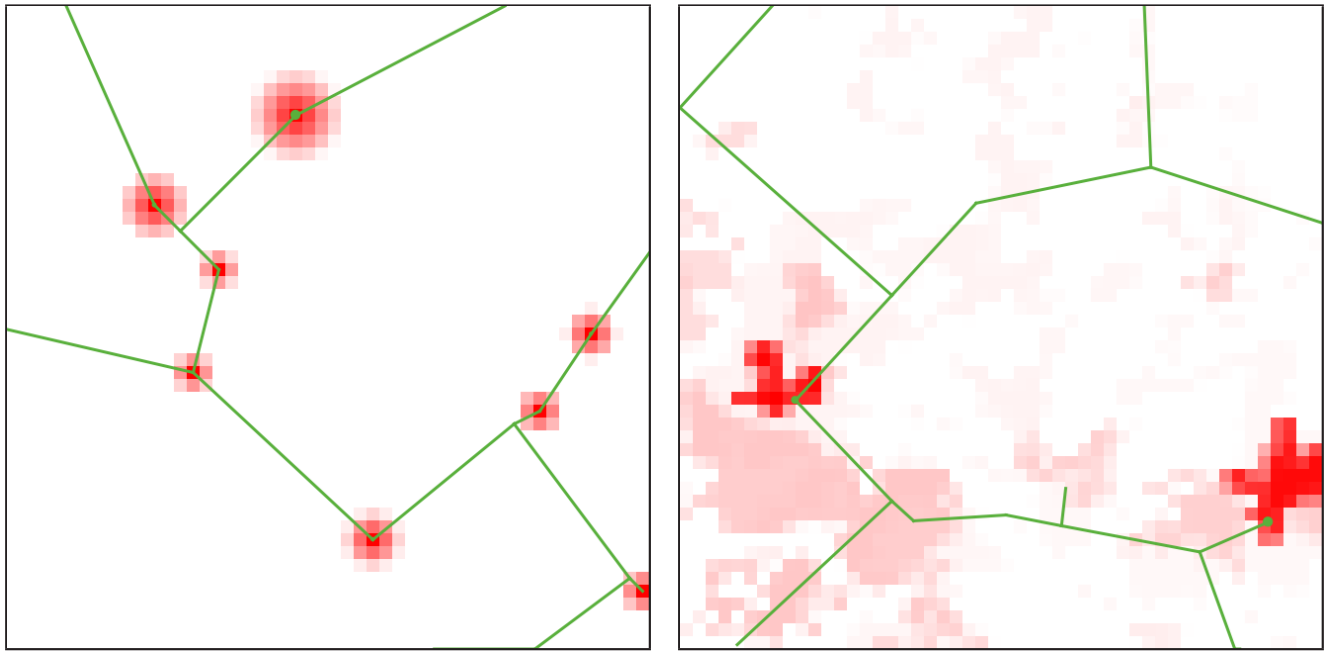
Model parameters

Heuristic	Param.	Name	Process	Domain	Default
Base	l_m	added links	growth	0; 100	10
	d_G	gravity distance	potential	0; 5000	500
	d_0	gravity shape	potential	0; 10	2
	k_h	gravity weight	potential	0; 1	0.5
	γ_G	gravity hierarchy	potential	0.1; 4	1.5
Random	γ_R	random selection	hierarchy	0.1; 4	1.5
	θ_R	random threshold	breakdown	1; 5	2
Cost-benefits	λ	compromise	compromise	0; 0.1	0.05
Biological	n_b	iterations	convergence	40; 100	50
	θ_b	biological th.	threshold	0.1; 1.0	0.5

Model setup

Synthetic setup: rank-sized monocentric cities, simple connection with bord nodes to avoid bord effects

Real setup: Population density raster at 500m resolution (European Union, from Eurostat)



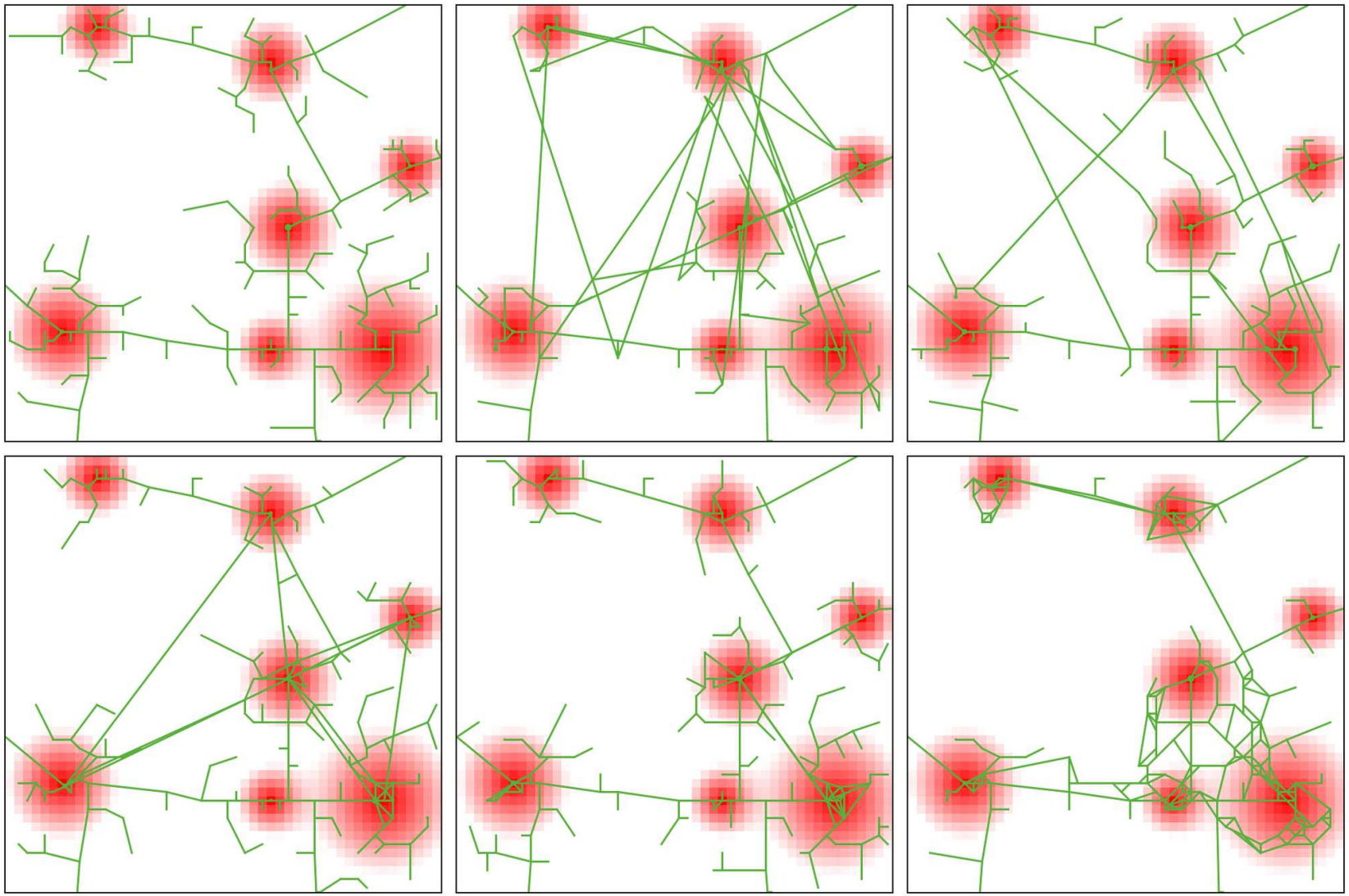
Stopping conditions: fixed final time; fixed total population; fixed network size.

Network Indicators

Network Topology measured by:

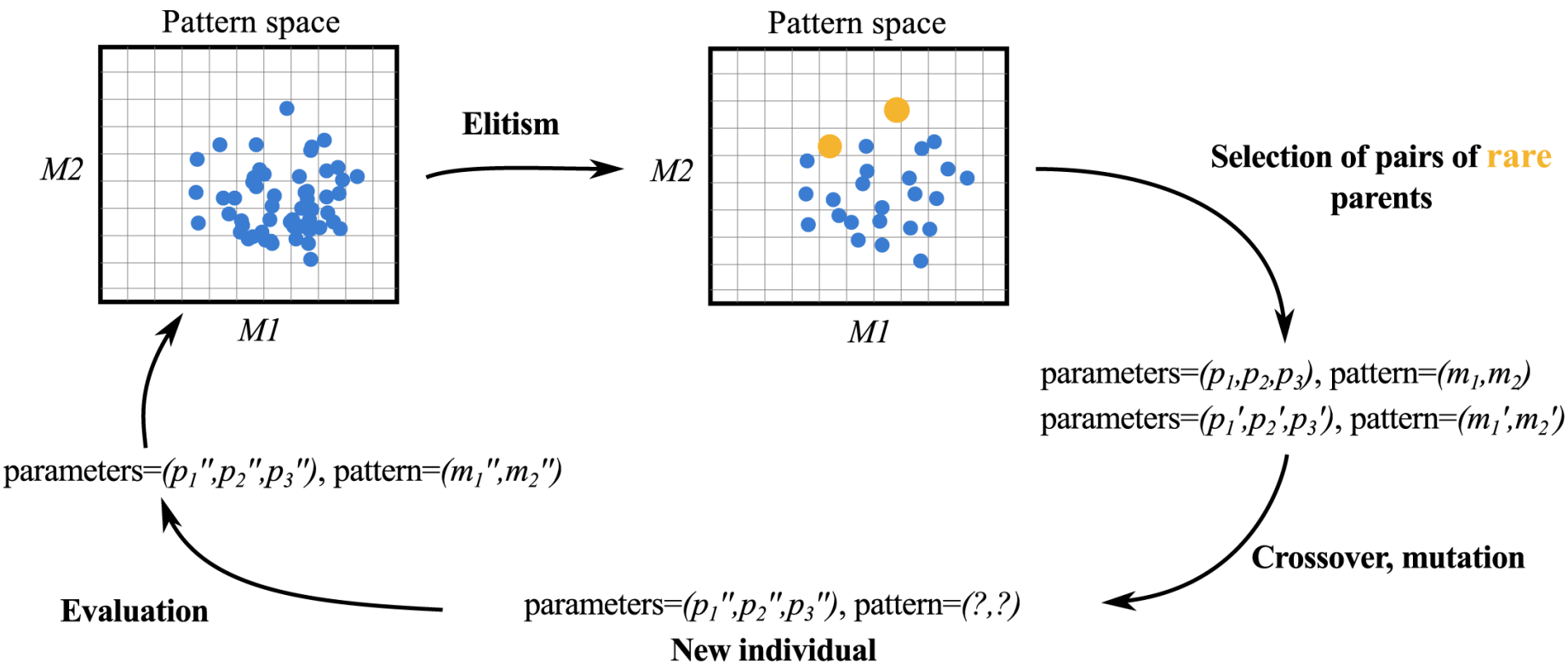
- Average betweenness and closeness centralities
- Efficiency (network pace relative to euclidian distance)
- Mean path length, diameter

Example of generated networks

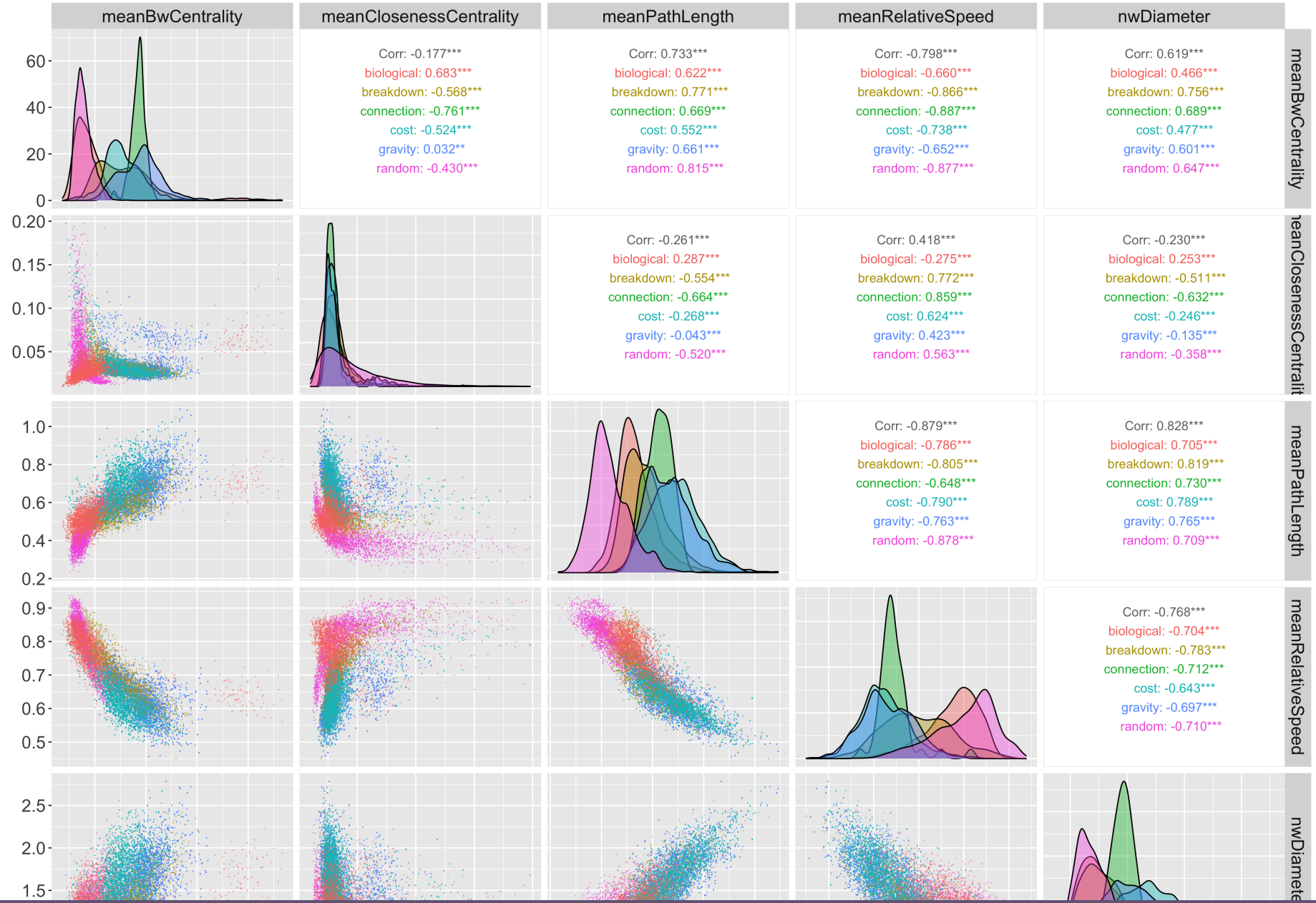


In order: connection; random; deterministic breakdown; random breakdown; cost-driven; biological.

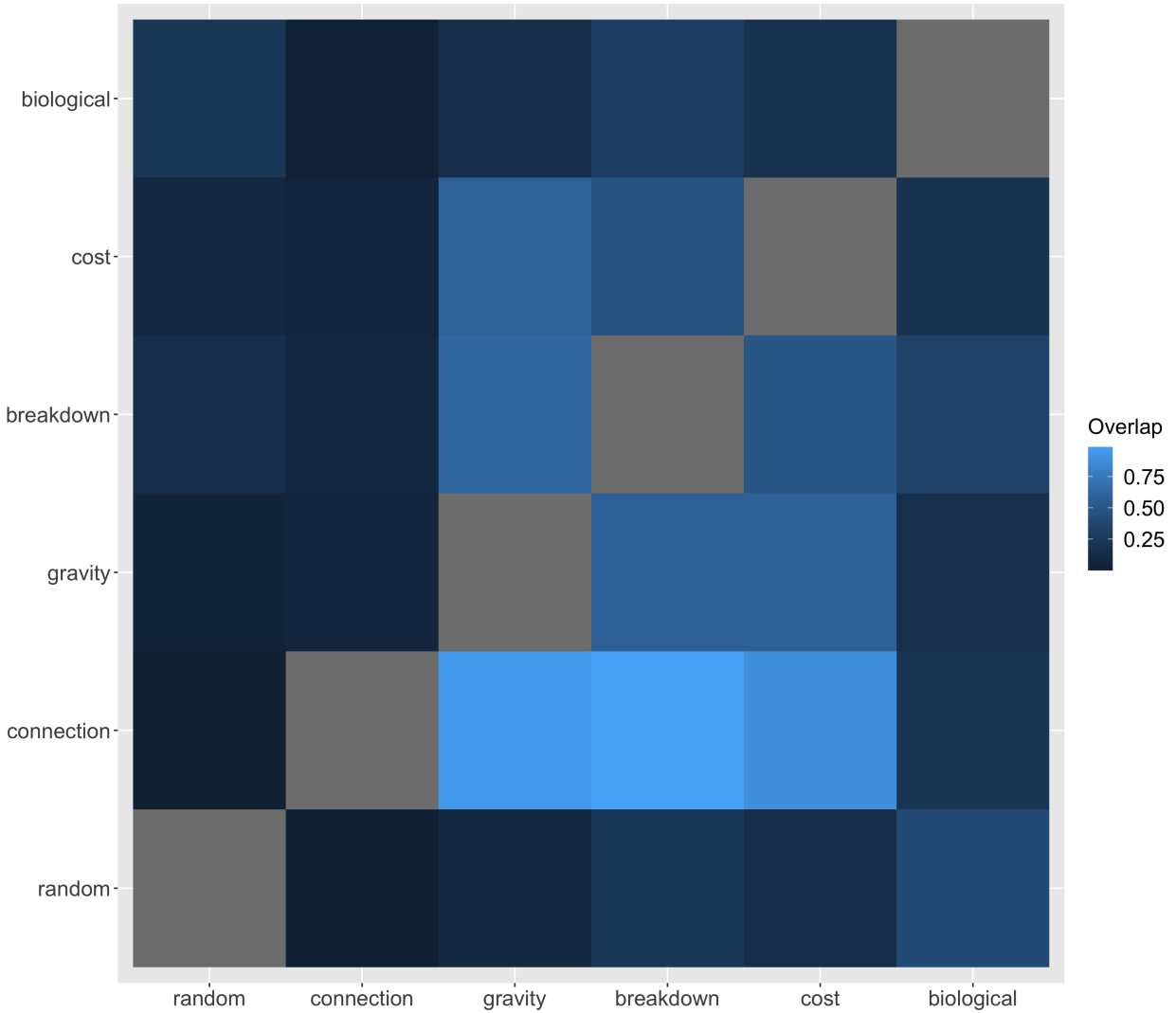
Pattern Space Exploration algorithm



Indicators feasible space



Hypervolumes



Discussion

Conclusion

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Open repositories

`https://github.com/JusteRaimbault/NetworkGrowth`

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