SIMULATION MODELS FOR SYSTEMS OF CITIES AND SUSTAINABLE DEVELOPMENT GOALS

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Sustainability trade-offs in systems of cities

→ urban systems induce both negative and positive externalities on many sustainability dimensions, leading to trade-offs between sustainable development goals [12]

→ simulation models for systems of cities at a macro scale are a tool to quantify and understand these [7]

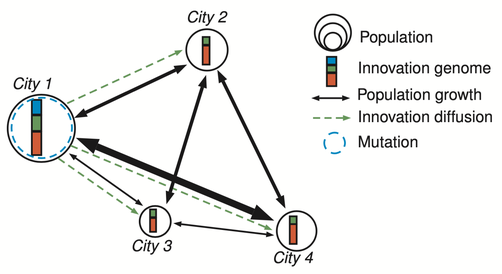
Research objective: develop a multi-model integrating several SDG dimensions to study and optimise many-dimensions trade-offs

Multi-modelling urban dynamics at the macro scale

→ based on Simpop models [2], cities populations are simulated on long time scales (100years) and small spatial scales (systems of cities) based on **spatial interactions** and **other dimensions captured by submodels** [6]:

- the hierarchical diffusion of innovations [3]
- economic exchanges between cities [1]
- the co-evolution between cities and the interurban transport network [4]

→ indicators quantifying sustainability regarding different goals: utility of innovations (SDG 9), transport emissions (SDG 13), transport infrastructure (SDG 9), economic inequalities (SDG 10), wealth (SDG 8)



Processes of spatial interaction and innovation diffusion for the innovation submodel

$$\begin{cases} S_0^{(t)} = S_t \\ S_{k+1}^{(t)} = M_k\left[S_k^{(t)}\right] \\ S_{t+1} = S_K^{(t)} \end{cases}$$

Sequential coupling of K submodels at each time step t

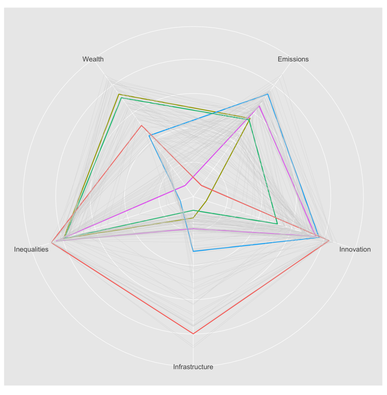
Application: SDG trade-offs in 5 dimensions

→ application to many-dimensions optimisation of indicators in synthetic systems of cities

→ model implemented in scala within the `spatialdata` library [5]

→ integration into the OpenMOLE software for model exploration and validation [9]

→ many-objective optimisation in 5 dimensions, using the NSGA2 genetic algorithm to obtain Pareto fronts, which provide trade-offs between the SDG indicators



Developments in progress for model validation

Question 1: ***how does the type of coupling for submodels influence emergent dynamics?***

→ comparison between strong couplings of submodels (all combinations of submodels in a sequential coupling) with weak couplings (one main model and other submodels only downstream to compute indicators without influencing population dynamics)

Question 2: ***do the simulated dynamics capture strong emergence?***

→ [8] applied information theory indicators proposed by [10] on a multi-scale model of innovation dynamics and found a large set of emergence regimes with a diversity search algorithm; application of the same approach to the macro-scale multi-model

Question 3: ***how to apply the model to a real system of cities?***

→ setup on the Chinese system of cities between 1980 and 2010 using data by [11] for populations, and GHSL for emissions and GDP; calibration on population trajectories

Future work: towards models applied to multi-scalar policy-making, requiring an extensive validation and understanding of model behaviour, and robust parametrisations on real-world systems

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