Proposals for 2021 Master Thesis subjects

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Research interests

My research interests include:

- methodology for the exploration, sensitivity analysis, and validation of spatial simulation models; I am a contributor of the OpenMOLE software for model exploration (`https://openmole.org/` (Reuillon et al., 2013));
- land-use transport interactions; I worked on the co-evolution of transportation networks and territories, and am currently working with the QUANT model (`http://quant.casa.ucl.ac.uk/`);
- agent-based and microsimulation models: I am developing open implementations of the MATSim transport model (`https://www.matsim.org/`), coupling it with QUANT and the SPENSER demographic microsimulation model (Lomax & Smith, 2017); I also developed stylised agent-based models for various aspects of urban complexity, for example industrial symbiosis (see project below);
- urban morphology and morphogenesis (see project below);
- urban dynamics and systems of cities (Raimbault, Denis, Pumain, 2020; Raimbault, 2020a); urban evolution (Raimbault, 2020b);
- text-mining applied to innovation (patent data) and bibliometrics (see project below).

You can propose a dissertation subject related to these fields and your own research interests. I give below four precise research projects extending previous works, for which I can provide datasets. You can also propose variations on these subjects based on your interests.

References

Lomax, N. M., & Smith, A. P. (2017). Microsimulation for demography. Australian Population Studies, 1(1), 73-85.

Raimbault, J. (2020a). Indirect evidence of network effects in a system of cities. Environment and Planning B: Urban Analytics and City Science, 47(1), 138-155.

Raimbault, J. (2020b). A model of urban evolution based on innovation diffusion. In Artificial Life Conference Proceedings (pp. 500-508). Cambridge: MIT Press.

Raimbault, J., Broere, J., Somveille, M., Serna, J. M., Strombom, E., Moore, C., Zhu, B. & Sugar, L. (2020). A spatial agent based model for simulating and optimizing networked eco-industrial systems. Resources, Conservation and Recycling, 155, 104538.

Raimbault, J., Denis, E., & Pumain, D. (2020). Empowering Urban Governance through Urban Science: Multi-Scale Dynamics of Urban Systems Worldwide. Sustainability, 12(15), 5954.

Reuillon, R., Leclaire, M., & Rey-Coyrehourcq, S. (2013). OpenMOLE, a workflow engine specifically tailored for the distributed exploration of simulation models. Future Generation Computer Systems, 29(8), 1981-1990.

Multi-dimensional urban morphology

Definitions and characterisations of urban morphology depend on the scale and the dimension considered. At an intermediate mesoscopic scale of a metropolitan area, both structure of transportation networks and the spatial distribution of population are complementary dimensions to quantify urban morphology. (Raimbault, 2019a) combines road network topology indicators with urban morphology indicators, and computes them for a 50km moving window on the full European Union. Some possible extensions building on this data and associated software that would be relevant for a project include:

- refining the indicators computed and their interpretation, possibly on a different area;
- using these as a proxy to extract some endogenous structure in the urban system, as e.g. (Raimbault, 2019b) uses the abstract network the indicator grid produces to apply multi-dimensional percolation;
- studying empirically and theoretically the spatial correlation patterns, i.e. how can the correlation matrix between indicators be estimated with the spatial sample? This can in particular imply theoretical investigations on spatial non-stationarity.

Dataset of road network and computed indicators are already available for Europe and China, but other regions and set of indicators can be provided depending on the direction taken. Software in R and scala to produce these are also openly available, and a technical assistance for the heavy computational tasks may be provided to the student.

References

Raimbault, J. (2019a). An urban morphogenesis model capturing interactions between networks and territories. In The mathematics of urban morphology (pp. 383-409). Birkhauser, Cham.

Raimbault, J. (2019b). Multi-dimensional Urban Network Percolation. Journal of Interdisciplinary Methodologies and Issues in Science, 5(5). https://jimis.episciences.org/5913

Spatial diffusion of innovation

The spatial diffusion of innovations is a crucial process in urban systems, for example in the interaction between cities but also at larger scales with company clusters. Patent data is a reasonable proxy to study technological innovation, and this project would consist in an empirical study of spatio-temporal patterns of innovation diffusion using different dimensions of patent data. (De Rassenfosse et al., 2019) provides geocoding for inventors for a recent period of 30 years, while the Patent City database (`https://github.com/Antoberge/patent_city`) provides such a geocoding for the US Patent Office from 1836 onwards, and also French, UK and German patents. Further data are available for USPTO and the European Patent Office, including citation network, technological classification, or semantic classification such as the one provided by (Bergeaud et al., 2017). The project would imply to use this data to:

- define measures and dimensions to characterise the diffusion of innovation (which can be citation flows, semantic flows), including the relevant scale of study;
- identify methods to understand spatio-temporal diffusion (network diffusion, reaction-diffusion, temporal GWR, hybrid methods, etc.);
- answer relevant thematic questions using these, i.e. by combining these to an appropriate theory of urban systems and additional data.

The student would be assisted for big data and computationally demanding tasks, but the subject both highly technical and mainly open, demanding also good research skills.

References

De Rassenfosse, G., Kozak, J., & Seliger, F. (2019). Geocoding of worldwide patent data. Scientific data, 6(1), 1-15.

Bergeaud, A., Potiron, Y., & Raimbault, J. (2017). Classifying patents based on their semantic content. PloS one, 12(4), e0176310.

Co-evolution of science and technology

An open question in the study of scientific knowledge production and of technological innovation is the quantification of the mutual influence of science and technology. In other terms, can a co-evolution of the two be observed, and to what extent does it depend on the field and on the time period. The Patent-to-Science dataset provides citation links from patents to scientific papers, what is a common practice. This project would imply to:

- define thematically and theoretically the co-evolution of science and technology, and develop methods to characterise it;
- study empirically the science-patent knowledge flow using the SciCit dataset;
- characterise knowledge dynamics within patents and papers separately (this can involve different datasets such as citation networks or semantic networks);
- identify the relevance of the patent-science knowledge flow and construct proxies of it.

Most of open issues involved in the project require advanced thematic and technical skills, and an empirical analysis of the SciCit dataset only would already be satisfying. The student will be assisted for big data and computationally demanding tasks, and also for data collection using for example the open tools provided by (Raimbault, 2019).

References

De Rassenfosse, G. and Verluise, C. (2019). Worldwide Patent-to-Science Citations dataset. `https://github.com/cverluise/SciCit`

Raimbault, J. (2019). Exploration of an interdisciplinary scientific landscape. Scientometrics, 119(2), 617-641.

Agent-based modeling industrial symbiosis networks

Pathways towards a circular economy include the emergence of industrial symbiosis networks, in the sense of a network of exchanges between inputs and outputs of industrial companies which would allow minimising the total waste and primary resource impact of industrial activities. While many factors play a role to build such networks, such as technical or legal issues, the spatial organisation of the industrial system has been shown to be crucial by (Raimbault et al., 2020). In this work, a stylised agent-based model was introduced, explored and applied as a proof-of-concept on pollutant exchanges for the Netherlands using the European Pollutant Release and Transfer Register database. The idea of the proposed subject would be to explore different possible extensions or applications of the model, including:

- refining the rules for agent behavior which for now only maximise an utility, using for example game theory;

- testing different scales of application: the model was designed for a regional scale with a spatial interaction component for relations between agents - exploring broader scale in a multi-level framework or smaller scales such as the intra-urban one, would reinforce the sensitivity analysis of the model;
- testing the influence of an explicit geography of transportation in the model, and more generally of the influence of the spatial configuration following the methodology of (Raimbault et al., 2019);
- collecting empirical data on real world industrial symbiosis systems and applying the model to these.

A literacy on agent-based modeling is required, but not necessarily advanced competences in programming and model exploration methods depending on the extension chosen (for testing alternative rules and applying on new data in particular).

References

Raimbault, J., Broere, J., Somveille, M., Serna, J. M., Strombom, E., Moore, C., Zhu, B. & Sugar, L. (2020). A spatial agent based model for simulating and optimizing networked eco-industrial systems. Resources, Conservation and Recycling, 155, 104538.

Raimbault, J., Cottineau, C., Le Texier, M., Le Néchet, F., & Reuillon, R. (2019). Space Matters: Extending Sensitivity Analysis to Initial Spatial Conditions in Geosimulation Models. Journal of Artificial Societies & Social Simulation, 22(4).