

# Complexity, Complexities and Complex Knowledges

*Discussion of Pr. Batty: "Complexity in Urban Systems"*

J. Raimbault<sup>1,2,\*</sup>

`juste.raimbault@polytechnique.edu`

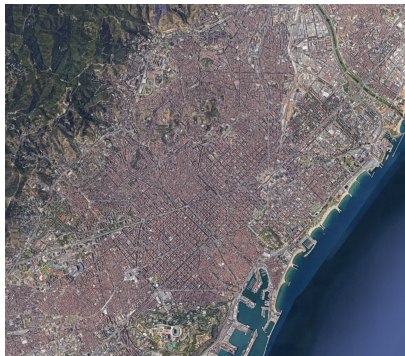
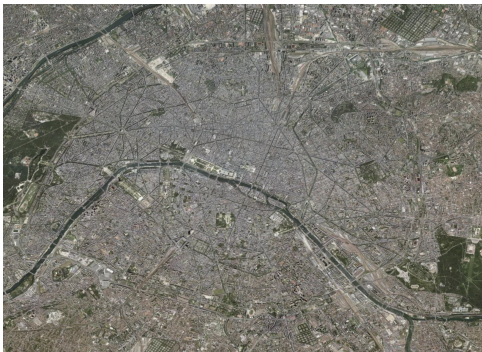
<sup>1</sup>UMR CNRS 8504 Géographie-cités

<sup>2</sup>UMR-T IFSTTAR 9403 LVMT

Geodiversity International Workshop

12-13th October 2017

# More or Less Complex Urban Systems ?



*Source: Geoportail, Google maps*

# Some Types of Complexity

*Various approaches to complexity, corresponding definitions, characterizations and measures. We consider:*

- Complex Systems as systems exhibiting Weak Emergence [Bedau, 2002]
- Computational Complexity:  $\mathbf{P} \neq \mathbf{NP}$ , Algorithmic Complexity (see [Moore and Mertens, 2011])
- Informational Complexity: information theory, Complexity profile [Allen et al., 2017]

→ *What are the links between these different types of complexities ?*

*Complex Systems require a minimal level of computational complexity*

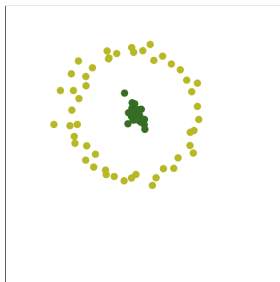
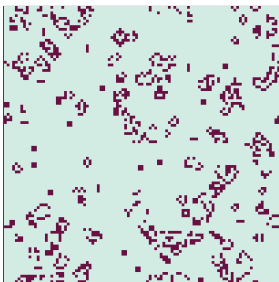
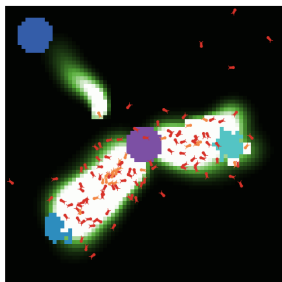
→ [Bolotin, 2014] shows that solving the Schrodinger equation with an arbitrary Hamiltonian is NP-complete

→ [Tošić and Ordonez, 2017] gives a lower bound for computational complexity of very simple ABMs when adding interactions with the environment

# Computation by Complex Adaptive Systems

*Computation is achieved by diverse Complex Systems*

→ Ant algorithm solves generalized TSP [Pintea et al., 2017]



*Sources. Ants, Game of Life: NetLogo Library; Swarm chemistry: implementation of [Sayama, 2007]*

## *Central role of information in Complex Systems*

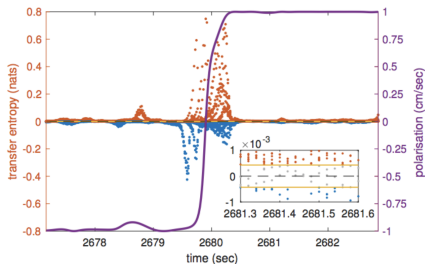
- Chua's local activity principle [Mainzer and Chua, 2013] drives local entropy for some reaction-diffusion systems
- Central role of Signals and their processing in Holland's approach to CAS [Holland, 2012]



(a)



(b)



(c)

*Role of transfer entropy in collective behavior in a school of fishes,  
from [Crosato et al., 2017]*

# Knowledge of the Complex

*Given that:*

- ① *Processes of knowledge production on Complex Systems necessitate high level of complexity for each aspect.*
- ② *They must translate the different type of complexities, and the relations between these.*

**Postulate :** Knowledge of the Complex has an inevitable reflexive nature, in the sense of recursive theories (knowledge on producer of the knowledge is part of the knowledge)

→ *Knowledge of the Complex* is thus Complex Knowledge (cf law of requisite complexity [Gershenson, 2015]). Link with an “Evolutive Rationality”, Complex Knowledge being both the product and the support of its evolution ?


- Non-reflexive approaches will never fully grasp Urban Complexity (or *Social Sciences are necessary*)
- Extension to other types of complexity such as Pumain's "disciplinary complexity" [Pumain, 2005] ? *Integrative approaches may be necessary*
- Role of new methods, tools, data (e.g. OpenMole, GarganText): *Towards Integration of Knowledge Domains*





## Reserve Slides


# References I

-  Allen, B., Stacey, B. C., and Bar-Yam, Y. (2017). Multiscale information theory and the marginal utility of information. *Entropy*, 19(6):273.
-  Bedau, M. (2002). Downward causation and the autonomy of weak emergence. *Principia: an international journal of epistemology*, 6(1):5–50.
-  Bolotin, A. (2014). Computational solution to quantum foundational problems. *ArXiv e-prints*.
-  Crosato, E., Jiang, L., Lecheval, V., Lizier, J. T., Wang, X. R., Tichit, P., Theraulaz, G., and Prokopenko, M. (2017). Informative and misinformative interactions in a school of fish. *arXiv preprint arXiv:1705.01213*.

 Gershenson, C. (2015).  
Requisite variety, autopoiesis, and self-organization.  
*Kybernetes*, 44(6/7):866–873.

 Holland, J. H. (2012).  
*Signals and boundaries: Building blocks for complex adaptive systems*.  
Mit Press, Cambridge, ISBN: 9780262525930.

 Mainzer, K. and Chua, L. O. (2013).  
*Local activity principle*.  
World Scientific.

 Moore, C. and Mertens, S. (2011).  
*The nature of computation*.  
OUP Oxford.



Pintea, C.-M., Pop, P. C., and Chira, C. (2017).

The generalized traveling salesman problem solved with ant algorithms.

*Complex Adaptive Systems Modeling*, 5(1):8.



Pumain, D. (2005).

Cumulativité des connaissances.

*Revue européenne des sciences sociales. European Journal of Social Sciences*, (XLIII-131):5–12.



Sayama, H. (2007).

Decentralized control and interactive design methods for large-scale heterogeneous self-organizing swarms.

*Advances in Artificial Life*, pages 675–684.



Tošić, P. T. and Ordóñez, C. (2017).

Boolean network models of collective dynamics of open and closed large-scale multi-agent systems.

*In International Conference on Industrial Applications of Holonic and Multi-Agent Systems*, pages 95–110. Springer.