

Title: Agent-Based Simulation in Complex Networks

Category: Introductory course

Personal information:

Dr. Miguel Rebollo
Univ. Politecnica de Valencia
Camino de Vera s/n
46022 Valencia (Spain)
+34 963877000 ext 73584
mrebollo@upv.es
<http://mreb.me/upv>
<http://about.me/mrebollo>

Abstract:

Agent-based models are a promising area to deal with adaptive complex systems, which are characterized by a collective behavior that leads to emergent phenomena. Networks constitute a mathematical framework to study complex, emergent, and self-organized environments, in which the relation among the participant entities plays a central role in the functioning of the community. The aim of this tutorial is to introduce the students to the area of complex networks. The course comprises a combination of theoretical concepts regarding the structure and dynamics of the most known network models, scale-free and small-world phenomena. The second part is a practical one in which these models will be implemented using Netlogo and Python.

Motivation and description

Many real systems are composed of elements that interconnect with each other, each one following its dynamics. In these cases, top-down approaches are not helpful for modeling systems and are often incapable of representing the behaviors that emerge from the group. In these cases, we are faced with what is called a complex system, and any change in its elementary components, even if small, leads to dramatic changes in the functioning of the global system.

Agent modeling is a possible answer to studying complex systems. The leading utility of multi-agent systems (MAS) is their ability to build groupings of autonomous entities (agents) that have their behaviors and decisions. They can complement simulations with more traditional techniques based on analytical, stochastic methods, or other models. Thanks to them, we can decompose complex problems into smaller and more accessible problems to solve.

The agent paradigm fits very well with the modeling of human beings as autonomous and intelligent entities endowed with will, the ability to determine their own course of action, communicate with each other, and learn and adapt to the environment. The agent-based approach provides a more natural representation of individuals than equations.

Networks play an important role in determining what the relationships between agents are like. Whether they are societies of people, other living beings, or artificial networks made up of artifacts, they all share common characteristics. From complex networks, we have studied how they are formed, what characterizes them, and how information is disseminated. Phenomena such as cascades, synchronization, or disease transmission are different faces of the same phenomenon, and it is essential to study and simulate societies' behavior.

Outline

1. Introduction to Complex Systems
2. Basics of Agent-based Modeling
3. Complex Networks. Characterization
4. Network Dynamics: synchronization, diffusion, opinion formation, spreading phenomena
5. Applications: cooperative games, markets, biological agents, social dynamics

Expected level and prerequisites

The course is appropriate for graduates in degrees with basic programming and mathematical competences (computer science, engineering, physics, or mathematics among others). It is recommended knowledge about

- programming, recommended elemental skills with Python
- classic graph theory
- basic statistics

Bibliography

- Uri Wilensky and William Rand (2015) *An Introduction to Agent-Based modeling*. MIT Press
- Severino Fernández Galán (2022) *Modeling Complex and Intelligent Systems with Netlogo*. Bellisco Ed.
- Barabasi, A.L. (2016) *Network Science*. Cambridge Univ. Press
- Guido Caldarelli, Alessandro Chessa (2016) *Data Science and Complex Networks: Real Case Studies with Python*. Oxford Univ. Press
- Herrera, Manuel, Marco Pérez-Hernández, Ajith Kumar Parlikad, and Joaquín Izquierdo (2020) Multi-Agent Systems and Complex Networks: Review and Applications in Systems Engineering. *Processes* 8, no. 3: 312
- Li An, Volker Grimm, Abigail Sullivan, B.L. Turner II, Nicolas Malleson, Alison Heppenstall, Christian Vincenot, Derek Robinson, Xinyue Ye, Jianguo Liu, Emilie Lindkvist, Wenwu Tang, (2021) Challenges, tasks, and opportunities in modeling agent-based complex systems, *Ecological Modelling*, Volume 457
- Shan Mei, Narges Zarrabi, Michael Lees, Peter M.A. Soot, Complex agent networks: An emerging approach for modeling complex systems (2015) *Applied Soft Computing*, Vol 37, pp 311-321,
- Wendt, A., Götzinger, M., Sauter, T. (2019). An Agent-Based Framework for Complex Networks. In: MacIntyre, J., Maglogiannis, I., Iliadis, L., Pimenidis, E. (eds) *Artificial Intelligence Applications and Innovations*. AIAI 2019. IFIP Advances in Information and Communication Technology, vol 559. Springer.