

# An introduction to Agent-Based Computer Modeling for Cognitive Research

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**Keywords:** Agent-Based Modeling; Multi-Agent Modeling;  
Complexity; Cognitive modeling

## Objectives

Agent-based modeling has been increasingly used by scientists to study a wide range of phenomena such as the interactions of species in an ecosystem, the collisions of molecules in a chemical reaction, or the food-gathering behavior of insects (Bonabeau, 1999; Wilensky & Reisman, 2006). Such phenomena, in which the elements within the system (molecules, or ants) have multiple behaviors and a large number of interaction patterns, have been termed *complex* and are collectively studied in an interdisciplinary field called *complex systems* or *complexity studies* (Holland, 1995). In such systems, the cumulative ('aggregate') patterns or behaviors at the macro level are not premeditated by the "lower-level" micro behaviors. Each element ('agent') follows local, simple rules, and the overall macroscopic pattern emerges from these multiple local behaviors. Complex-systems methods and perspectives arose from the natural sciences, but complexity, emergence, and micro and macro levels of description of phenomena are all highly relevant to research in the social sciences. Indeed, the recent decades have seen a surge in social-science studies employing ABM (Epstein & Axtell, 1996; Axelrod, 1997). Recently ABM has also been used to illustrate aspects of cognitive development (see Abrahamson & Wilensky, 2005, Blikstein, Abrahamson & Wilensky, 2006) and collaboration and group work in classrooms (Abrahamson, Blikstein & Wilensky, 2007). This approach is particularly relevant in cognitive research since not all macroscopic behaviors of the system have to be known beforehand, which is typical for several cognitive processes, and is timely for several reasons: (i) data-collection techniques are advancing quickly, and modeling techniques could help make sense of the data, (ii) researchers are in urgent need of low-cost, rapid-prototyping languages for modeling, and (iii) as models of cognition get more complex, the computer modeling is increasingly important.

This tutorial will present an easy-to-learn but sophisticated agent-based modeling environment (NetLogo, <http://ccl.northwestern.edu/netlogo>) and examine many of the concepts and problems associated with multi-agent modeling through a hands-on learning experience. In addition, the participants will be exposed to participatory multi-agent simulation and how it can be used as a research tool or as a low-cost data-collection platform for research in the cognitive sciences.

## Outline and Pedagogy

Participants in this tutorial will:

- Receive an overview of the conceptual framework of agent-based modeling.
- Explore existing models in psychology and cognitive science, including seminal models in the field.
- Explore one networked participatory simulation environment.
- Learn the programming basics of NetLogo, a free, well-supported, and widely used platform for multi-agent simulation, and build a simple model. We have shown in previous research that students can create a working model in less than 3 hours.

The author will provide written and online materials for the tutorial, simple programming challenges, as well as a series of slideshow presentations. Online tutorials can be found at:

<http://ccl.northwestern.edu/netlogo/docs/tutorial1.html>,  
<http://ccl.northwestern.edu/netlogo/docs/tutorial2.html>, and  
<http://ccl.northwestern.edu/netlogo/docs/tutorial3.html>.

Participants should follow the online tutorials prior to the conference as preparation for the tutorial.

Over the course of the hands-on part of the tutorial, participants will be encouraged to depart from scientific issues that they themselves face in their professional life, and try to create a simple NetLogo model to simulate it.

The instructor has extensive experience conducting such workshops, as well as all the needed materials and techniques to have novices learn the language in just some hours. The instructor has generated some of the first ABM models of cognitive processes using tools such as NetLogo; therefore has experience translating cognitive research into agent-based models.

The workshop will be an introduction to the agent-based approach, but participants will acquire the needed skill to create simple models on their own, and know how and where to learn further in order to be able to implement cognitive models.

## Target audience

The primary audience will be researchers with little or no experience in computer modeling. Also, we will target experts interested in using agent modeling as rapid prototyping tools, and researchers wanting to speed up development of simulations by avoiding the construction of a custom tool, or willing to broaden their range of tools for

modeling and simulation. There is no prerequisite for the tutorial.

### Schedule (Full day)

09:00 - 10:00	Introduction to ABM and NetLogo
10:00 - 10:30	Exploring existing models and networked participatory simulations.
10:30 - 12:00	Basics of the NetLogo Language and modeling techniques, simple modeling challenges, hands-on modeling with NetLogo (part 1)
11:30 - 12:30	Lunch
12:30 - 3:30	Hands-on modeling with NetLogo (part 2)
3:30 - 4:00	Participants' presentations, final discussion

### Materials needed

- Projector.
- Tables and chairs for the participants.
- One laptop per participant (Windows, Mac, or Linux, participants can bring their own).
- NetLogo software installed on all computers (free download, <http://ccl.northwestern.edu/netlogo>)
- Spreadsheet software (Excel, Open Office, or similar).
- No commercial software will be required.

### About the author

#### Bio and experience

Paulo Blikstein (M.Eng. University of São Paulo, MSc. MIT Media Lab; PhD. Learning Sciences, Northwestern University) is an assistant professor at Stanford University, at the School of Education and (by courtesy) Computer Science. Blikstein's research focuses on cognitive modeling using ABM, as well as the Bifocal Modeling framework, which connects multi-agent-based simulation and the physical world, using sensor arrays, micro-actuators and rapid prototyping equipment, such as 3D printers. He has also been developing multi-agent-based simulation systems for undergraduate students in engineering, and conducting agent-based modeling tutorials in various conferences and research centers across the world. Together with colleagues from Northwestern University and Berkeley, Blikstein has been one of the pioneers in the use of ABM for cognitive research, following a series of papers which have been published at different conferences since 2005.

#### Selected publications in the field

Blikstein, P., Abrahamson, D., & Wilensky, U. (2005). **NetLogo: Where we are, where we're going.** In M. Eisenberg & A. Eisenberg (Eds.), Proceedings of the

annual meeting of Interaction Design and Children 2005. Boulder, Colorado.

Blikstein, P., Abrahamson, D., & Wilensky, U. (2006). *Minsky, Mind, and Models: Juxtaposing Agent-Based Computer Simulations and Clinical-Interview Data as a Methodology for Investigating Cognitive-Developmental Theory.* Paper presented at the Jean Piaget Society Annual Meeting 2006.

Blikstein, P., & Wilensky, U. (2006). *Learning About Learning: Using Multi-Agent Computer Simulation to Investigate Human Cognition.* Paper presented at the International Conference of Complex Systems 2006, Boston, USA.

Rand, W., Blikstein, P., & Wilensky, U. (2006). *Widgets, Planets, and Demons: The Case for the Integration of Human, Embedded, and Virtual Agents via Mediation.* Paper presented at the Swarmfest 2006, South Bend, IN, June 23-24.

Blikstein, P., & Wilensky, U. (2006). *'Hybrid modeling': Advanced scientific investigation linking computer models and real-world sensing.* Paper presented at the Seventh International Conference of the Learning Sciences, Bloomington, USA.

#### Tutorials conducted on similar topics

- AAMAS 2005, Utrecht, Holland.
- Interaction Design for Children 2005, Boulder, USA.
- Integrated Systems Laboratory, University of São Paulo, Brazil, 2005
- Integrated Systems Laboratory, University of São Paulo, Brazil, 2004
- Northwestern University, Summer 2006
- Stanford University, Fall 2008.

Apart from several tutorials at conferences and professional meetings, Blikstein has instructed individually approximately 50 undergraduate students in ABM as part of his dissertation research, being very well versed in the pedagogy of teaching ABM for novices.

#### Additional references (not mentioned above)

Bonabeau, E., Dorigo, M., & Thérault, G. (1999). *Swarm intelligence: From natural to artificial systems.* London: Oxford University Press.

Wilensky, U., & Reisman, K. (2006). Thinking like a wolf, a sheep or a firefly: Learning biology through constructing and testing computational theories -- an embodied modeling approach. *Cognition & Instruction*, 24(2), 171-209.

Holland, J. (1995). *Hidden order: How adaptation builds complexity.* Reading, MA: Helix Books/ Addison-Wesley.