

# MULTI-AGENT SIMULATION AND NETLOGO IN THE INTRODUCTORY COMPUTER SCIENCE CURRICULUM\*

## *TUTORIAL PRESENTATION*

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## **ABSTRACT**

The tutorial introduces the NetLogo programming language and presents an approach to an introductory computer science course based on multi-agent simulation and NetLogo. This course has been taught at Middlebury College in Vermont for the past five years, both as a non-majors (CS0) introductory course and as first semester introduction to programming class (CS1) for computer science majors. As a non-majors course, the immediate applicability of the subject matter makes it especially appealing to students in the sciences and in economics, providing an introduction to *individual-based modeling* and *complex adaptive systems*. The power and simplicity of the NetLogo language allows students to develop complex simulations in their first semester. As a majors course, the language provides a basis for important CS1 topics including: selection, iteration, recursion, lists, data types, Boolean logic, algorithmic thinking, and object-oriented concepts. The applicability of the topic and the complexity of the programs that a first semester student can develop also aid in recruitment and retention of computer science majors.

## **OVERVIEW**

Multi-Agent Simulation is a growing field of study in computer science and in several application disciplines including especially biology and economics. In many traditional areas of computer simulation, models are based on complex equations describing global knowledge. In multi-agent simulation, and especially its subfield known as *individual-based modeling*, the model is based the behaviors of individual (algorithmic) agents, each of which makes decisions based on *local* (rather than global)

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knowledge. The overriding principle is often known as *emergent behavior* since the global outcome emerges from the behaviors of individuals, and is discovered over time using simulation. Furthermore, in *individual-based modeling*, agents grow and change over their lifetimes, and there is variance among individuals of the same species.

NetLogo is a powerful programming language designed to provide many of the primitives needed for multi-agent simulation. It has a syntax based on the Logo language, which was designed for education purposes, but it provides a dictionary of high-level instructions for concurrent behaviors of individual agents. It has iteration constructs as well as if-else statements, and procedures and functions with call-by-value. It supports recursion and the design of data structures. Although NetLogo is procedural, it shares many features with object-oriented programming languages; the agents as well as the patches that comprise the spatial environment through which agents move can be understood in an object-oriented context. The agents are also fundamentally algorithmic, and because of the visual component they provide an excellent framework for students to learn algorithmic reasoning.

Middlebury College is a small, rural, residential liberal arts college of approximately 2400 students, with a computer science major that typically graduates eight to twelve majors per year. In most years, the department has four full-time teaching faculty, offering twenty courses or course sections (an average of ten per semester). Multi-agent simulation using NetLogo was first taught at Middlebury as an introductory programming course (with no prerequisites) designed for non-majors. The course was taught by a computer science professor, with a computer science course designation, but the primary audience was students in the environmental studies, biology, and economics majors. The course counted as a science credit toward the environmental studies major, and was frequently recommended to economics and biology majors as well, and students in these majors used the material in upper level courses and independent research.

The enrollment of the course has grown steadily over five years, and many students enjoyed the material enough that they enrolled in further programming courses in the computer science major. The course was modified in 2010-2011 to count toward a recently revised computer science major as a substitute for the traditional CS1 course; student completing the multi-agent simulation course had met the prerequisite for taking CS2, which is currently taught in Java. Thus the current version of the course counts both as an elective in the environmental studies major, and may also be used as the first course in the computer science major in either a traditional track or a track emphasizing spatial and geometric computing.

## TUTORIAL OUTLINE

The majority of the tutorial will be devoted to an introduction to the NetLogo language, presenting or developing several in-class examples and homework coding assignments that might be used over the duration of a one-semester course. We will begin with a brief introduction to the principles of multi-agent simulation and individual-based modeling, emphasizing how it is different from tradition modeling based on complex global equations. This will be followed by a more extensive hands-on presentation of the features of the NetLogo language, designed specifically as a multi-agent simulation language. Participants will be encouraged to following along with the development of

various models on their own computers or on lab computers. We will conclude with a brief overview of the syllabus of a 12-week semester course based on multi-agent simulation and NetLogo, including a summary of the "breadth" topics that are also covered in the class.

#### **ACKNOWLEDGEMENTS AND RESOURCES**

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