Chapter 48
Modelling and Simulating Complex Systems in Biology:
Introducing NetBioDyn – A Pedagogical and Intuitive Agent-Based Software

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ABSTRACT

Modelling and teaching complex biological systems is a difficult process. Multi-Agent Based Simulations (MABS) have proved to be an appropriate approach both in research and education when dealing with such systems including emergent, self-organizing phenomena. This chapter presents NetBioDyn, an original software aimed at biologists (students, teachers, researchers) to easily build and simulate complex biological mechanisms observed in multicellular and molecular systems. Thanks to its specific graphical user interface guided by the multi-agent paradigm, this software does not need any prerequisite in computer programming. It thus allows users to create in a simple way bottom-up models where unexpected behaviours can emerge from many interacting entities. This multi-platform software has been used in middle schools, high schools and universities since 2010. A qualitative survey is also presented, showing its ability to adapt to a wide and heterogeneous audience. The Java executable and the source code are available online at http://virtulab.univ-brest.fr.

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INTRODUCTION

The theory of complex systems has become more and more relevant over the last thirty years to understand concepts such as emergence and self-organization and their role in biological, physical, chemical and social systems (Jacobson & Wilensky, 2006). Modelling and simulating these concepts behind the theory of complex systems is now very important, especially for biologists (students, teachers, researchers). For example, recent works have highlighted the complementarity of modelling both bottom-up and top-down (aggregated) approaches (Stroup & Wilensky, 2014). It has been shown though that teaching and learning complex systems are challenging tasks, and raise a lot of pedagogical issues. The two main issues are:

1. A widely taught top-down approach that have led students to think in that unique way; and
2. System dynamics that are difficult to understand and can be non-linear and counter-intuitive (Jacobson & Wilensky, 2006).

Among different strategies, the use of Multi-Agent Based Simulations (MABS) in research, teaching and learning has proved to be an efficient way of answering (some of) these issues (Epstein, 1999; Jacobson & Wilensky, 2006; Ginovart, 2014). Indeed, the individual-based approach, in opposition to a population-based approach (such as ordinary differential equations), focuses on the entities of the system, their behaviour and their local interactions to explain the global system's behaviour. As such, this concept is easier to understand, more intuitive and do not require advanced mathematical skills (Ginovart, 2014). The use of computer tools to implement these models in virtual environments and simulate them allows researchers and students to generate hypothesis, test them and, especially for students, build their knowledge more efficiently (in a process of *abduction* (Houser, 1992)), see Section 2.2). NetLogo (Wilensky, 1999) is a good example of such agent-based software, and has been used in a lot of works, both in education (Gammack, 2015) and research (Banitz, Gras, & Ginovart, 2015).

This chapter focuses on how to teach complex biological systems to, for example, university students in Biology, middle school and high school students; students who often do not have any experience in computer programming, and/or are reluctant to implement any code. The problem is that most of agent-based software require knowledge and skills in programming languages such as Java (*e.g.* the Repast software (North, Collier, & Vos, 2006)) or the NetLogo environment. This is an issue that occurs more and more as the use of agent-based software, both in research and teaching, grows in social and life sciences. In (Ginovart, 2014) and (Gkiolmas, Karamanos, Chalkidis, Skordoulis, & Papaconstantinou, 2013), a model of a predator-prey system is used with NetLogo to help respectively first-year and high-school students to understand individual-based approaches and eco-systemic mechanisms. Despite its interest, this model is a ready-made one, coded in NetLogo, where the students can change some parameters of the simulation, but are not implied in the process of creating their own simulation from scratch. Indeed, implementing this model is considered as "a hard task" by the students (Ginovart, 2014) and could be counterproductive: looking for errors in the code instead of thinking at the rightness of the model. The authors argue that using pre-existent models could have a part in preventing students for building their own system's *representation* (this point will be developed in Section 2.2). The gap between most of agent-based software prerequisites and the actual programming skills of students (and sometimes researchers) in these fields has to be dramatically reduced and the processes of implementing a model and simulate it should be more intuitive.