Introduction
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For almost the last ten years, the agent-based modelling approach has allowed us to conceptualize and simulate an organized population of agents that have interactions among themselves and with their environment. In the social sciences, such an approach allows us to formalize complex situations with multiple scales (either spatial, temporal or organizational) and heterogeneous agents engaged in social activities as well. These agents can have more or less developed capabilities, from *reactive agents* constitutive of the *collective intelligence* [BON 94] to *cognitive agents* having more sophisticated patterns of rationality, as anticipated by Simon [SIM 69], those patterns being formalized for instance by using appropriate logics [WOO 00, SUN 05]. This book is a translation of the volume previously published in French and made up of the conferences given during the summer research school, *Agent-based Modelling and Simulation of Complex Systems for the Social Sciences: Principles and Methods of Design and Use*, organized by Frédéric Amblard, Nils Ferrand and Denis Phan in Porquerolles, France, in September 2005. In this new edition, the book displays some differences compared to the first edition in French. A chapter written by the Commod (Companion Modelling) group has not been incorporated into this edition but it will appear in English in the *Ecological Modelling* journal. Some of the second and third parts of the book that were dedicated to economics and spatial modelling will be published in

English as separate volumes. New chapters that seem to us important in preparing a more complete handbook, such as an introduction to UML and the question of emergence in multi-agent systems have been incorporated into this volume. The reader will also find a more specific appendix on epistemological issues in social sciences and economics. As a whole, the book addresses the specialist, with a description of the domain and the current challenges, and beginners as well, with some examples in the social sciences and some hints on how best to use this approach. It also proposes some insights into recent developments and new questions posed to agent-based modelling, at a moment when the field approaches a decisive turn, beyond its emergence phase (see Chapter 6 and [TES 06]).

Chapters 1 and 2, written by Jacques Ferber and Eric Ramat, present the computer sciences foundation of this approach, without neglecting its impact on modelling and simulation practices. Chapter 3, written by Vincent Ginot and Hervé Monod, discussed the statistical methods used to analyse data generated by these *in silico* experiments that are agent-based simulations. Chapter 4, co-authored by Frédéric Amblard, Pierre Bommel and Juliette Rouchier, deals with the assessment and the so-called "validation" of agent-based models and simulations. Following the discussions we had in Porquerolles about the methodological and epistemological questions associated with our domain, and as this chapter raises some of these questions, it was important for us to extend it with two additional contributions: *Appendix 1: Epistemology in a Nutshell—Theory, Models, Simulations and Experiment* by Denis Phan, Anne-Françoise Schmid and Franck Varenne and *Appendix 2: Philosophy of Social Science in a Nutshell—From Discourse to Model and Experiment* by Michel Dubois and Denis Phan.

In Chapter 5, Nigel Gilbert, sociologist and pioneer of simulation in the social sciences [GIL 95], draws up a panorama of the methods, problems and results in this domain, followed, in chapter 6, by another pioneer, Robert Axtell, economist and computer scientist [EPS 96]. For the latter, agent-based modelling and simulation are "at the end of the beginning" and therefore are entering a new phase, characterized by the conjunction of accumulated knowledge and the increase of the computer power and programming languages. Chapter 7, written by Lena Sanders, is concerned with the history of modelling and simulation in urban geography, but it also raises some questions that concern all the social sciences as well as geography. Chapter 8, by Pierre

Livet, extends epistemological thought in social science, by questioning the cognitive and epistemic status of simulation. Chapter 9 written by Nils Ferrand, presents the framework of a participative approach, using agent-based modelling with the actors but using also the artefact produced by this modelling process in order to discuss concrete problems of collective decision-making, for instance dealing with resources management.

The second part of this book is dedicated to case-based studies and exercises in agent-based modelling and simulation in economics and geography. Thus, Chapter 10, written by Denis Phan, introduces and exemplifies the articulation between automata networks and multi-agent systems. Chapter 11, authored by Gilles Daniel, exemplifies the modelling, implementation and exploration of a multi-agent model. Chapter 12, co-authored by Pierre Bommel and Jean-Pierre Müller introduces UML, a graphical modelling language that is frequently used to make conceptual models. Chapter 13, written by Eric Daudé and Patrice Langlois compares three different implementations of Schelling's model; it illustrates some of the difficulties involved in moving from a partially described conceptual model and an implemented model. The last Chapter by Jean-Louis Dessalles, Jean-Pierre Müller and Denis Phan is concerned with the emergence issue in multi-agent systems, it is written . The book ends with two appendices written respectively by Denis Phan, Anne-Françoise Schmid and Franck Varenne, and by Michel Dubois and Denis Phan, dealing with epistemological issues linked on the one hand to simulation and on the other hand to social science and economics.

Agent-based modelling has many sources: computer sciences [FER 99, WOO 02], the stream of adaptive complex systems in physics or in biology [HOL 75, WEI 91, NAM 06] or the domain of artificial life [LAN 89]. It has also been used in ecology with the individual-based modelling (IBM) approach. This approach is based on a particular property of multi-agent architectures that allows us to formalize and activate individual properties that are specific to the agents, as interaction and communication modalities between the system's constitutive entities (the agents, but also more complex entities like groups of agents for instance - see Chapter 1). The agent-based approach can be linked in some disciplines to well-known conceptual frameworks (such as methodological individualism in sociology or in economics). And in some cases it permits completion of those conceptual frameworks, thanks to the integration of relational or organizational elements that

can be formalized as graphs on which agents are interacting, giving to the resulting system the dynamical properties of a complex adaptive system. The multi-agent architectures help in explanation of, on the one hand the nature of the relations between the social environment of the agents (organizational or institutional elements, relational structures, etc.), and on the other hand the individual determinants of the action of the agents (the cognitive dimension, see for instance Chapters 1 and 14). They offer also an adequate framework to investigate the question of the ontology of "social objects" [LIV 00] and of "social causalities", for instance through emergent phenomena (see Chapters 5 and 14).

Geography, whose subject of study is inscribed in both space and time, raises the question of the constitution of entities by composition in architectures that are both multi-level and multi-perspectival. Multi-scale representation in space also poses questions about temporal patterns of the processes under consideration (see Chapter 7). Finally, the notions of model and modelling are central to this book although not presented in a systematic way (see Appendix 1, Section 3; Appendix 2, Section 4 and [MOR 99]). Obviously, between the potentialities proposed in Chapters 1 and 2 by computer scientists and effective realization in the social sciences, a gap has to be filled. Multi-agent models, that can be seen as "complements" or "substitutes" to classical formalisms (see Chapter 6), may have the objective of reproducing stylized facts or observed phenomena (see Chapter 7), or can be based on the coupling of models of different nature (see Chapter 2). In all cases they bring new methodological thought to the application domain. Is it a new epistemological "computationalist" point of view, as Varenne would see it? (See Appendix 1, Section 3 and [VAR 06]). Although we cannot answer all of these questions, they are addressed in this book.

REFERENCES

[BON 94] Bonabeau E., Theraulaz G. (eds.) *Intelligence collective*, Paris, Hermes, 1994.

[CHA 82] Chalmers A.F. *What Is This Thing Called Sciences?* University of Queensland Press, 1982 (2nd edition).

[EPS 96] Epstein J.M. Axtell R. *Growing Artificial Societies, Social Sciences from the Bottom Up*, Washington D.C.Brooking Institution Press, Cambridge, Mass., MIT Press, 1996.

[FER 99] Ferber J. *Multi-Agent Systems. An Introduction to Distributed Artificial Intelligence,* London, Addison Wesley, 1999.

[GIL 95] Gilbert N., Conte R. (eds.) *Artificial Societies: The Computer Simulation of Social Life*, London UCL Press, 1995.

[HOL 75] HOLLAND J. *Adaptation in Natural and Artificial Systems*, Ann Arbor, Mich, University of Michigan Press, 1975; 2nd edition, MIT Press, 1992.

[LAN 89] LANGTON C.G. (ed.) *Artificial Life*, Redwood Ca., Addison-Wesley, 1989.

[LIV 00] LIVET P. OGIEN R. *L'enquête ontologique, du mode d'existence des objets sociaux*, Paris, éditions de l'EHESS, 2000.

[MOR 99] MORGAN M.S., MORRISON M. *Models as Mediators*, Cambridge, Cambridge University Press, 1999.

[NAM 06] NAMATAME A. *Adaptation and Evolution in Collective Systems*, Advances in Natural Computation Vol. 5, World Scientific, 2006.

[SIM 69] SIMON H.A. *The Sciences of the Artificial*, Cambridge, Mass., MIT Press, 1969.

[SUN 05] SUN R. *Cognition and Multi-agent Interaction: From Cognitive Modeling to Social Simulation*, Cambridge, Cambridge University Press, 2005.

[TES 06] TESFATSION L., JUDD K.L. *Handbook of Computational Economics, Vol. 2: Agent-Based Computational Economics*, Amsterdam, New York, Elsevier North-Holland, 2006.

[VAR 06] VARENNE F. *Les notions de métaphores et d'analogie dans les épistémologies des modèles et des simulations*, Paris, éditions Pétra, 2006.

[WEI 91] WEISBUSCH G. *Complex Systems Dynamics*, Addison Wesley Longman, 1991.

[WOO 00] WOOLDRIDGE M. *Reasoning about Rational Agents*, Cambridge Mass., MIT Press, 2000.

[WOO 02] WOOLDRIDGE M. *An Introduction to Multiagent Systems*, John Wiley & Sons, 2002.