BOOK REVIEW

Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations

Reviewed by Jorge Louçã, Lisbon University Institute, Portugal
John Symons, University of Texas at El Paso, USA

Yoav Shoham, and Kevin Leyton-Brown
Multiagent Systems: Algorithmic, Game-Theoretic, and Logical Foundations
Cambridge University Press
ISBN: 978-0521899437
504 pages
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The stated purpose of this book is to offer a complete overview of the ideas and techniques involved in modeling, reasoning about, and building multiagent systems. It is meant to serve both as a textbook for use in graduate classes and a handbook for researchers. The target audience is broad, but in our opinion it is likely to prove an indispensable resource for everyone working in the field of multiagent systems for many years to come.

It is a highly ambitious project, with many of the virtues and vices one usually associates with a textbook. It sometimes rushes over complex issues in the manner of an introductory text while generally assuming a level and breadth of mathematical preparation which one would expect in an advanced graduate student. The book will be useful as a resource for upper-level undergraduate and beginning graduate level classes on multiagent systems, but it will almost certainly require the addition of supplementary materials. In this review, we will outline the contents of the book. None of our criticisms of this book should obscure the fact that we believe that there is no other book like this currently available and we find it to be an excellent resource.

While they recognize that basic notions like ‘agent’ do not have a stable, agreed-upon definition in the scientific community, the authors define the space of problems and approaches to multiagent systems in a way which encompasses most approaches in the literature. According to Shoham and Leyton-Brown, multiagent systems “are those systems that include multiple autonomous entities with either diverging information or diverging interests, or both.”
(xiii) This is a highly inclusive and reasonable
characterization. However, when combined with their desire to provide a complete survey of multiagent systems the definition commits the authors to tackling an enormous amount of material.

The theoretical concepts discussed in the book reflect the diversity of foundational approaches to multiagent systems, coming from artificial intelligence, distributed systems and other computer science related domains, macroeconomics, operations research, analytic philosophy, and linguistics. Meanwhile, the technical approaches used in formalizing and exemplifying algorithms come from logic, probability theory, game theory, and optimization.

Each of the thirteen chapters concerns a specific problem or approach. The chapters are organized into a set of “blocks”, each of which can be considered independently. Each block is comprised of one or more sequentially dependent chapters. A block of material is devoted to the main notions of coordination, competition, algorithms, game theory, and logic in multiagent systems.

The first block is composed by chapters 1 and 2, concerning distributed problem solving (DPS). In DPS specific tasks are assigned to agents which coordinate their actions to solve some global problem. The material present in this first block is mainly algorithmic, concerning specifically constraint satisfaction issues and algorithmic methods for distributed dynamic programming, action selection in distributed MDPs, auction-like optimization procedures for linear and integer programming, and social laws.

As discussed in Chapter 1, constraint satisfaction problems are characterized by a set of variables, domains for each of the variables, and constraints on the values that the variables might take on simultaneously. “The role of constraint satisfaction algorithms is to assign values to the variables in a way that is consistent with all the constraints, or to determine that no such assignment exists.” (2) The authors review various approaches to these algorithms, explaining the asynchronous backtracking algorithm in an appropriate level of detail.

Chapter 2 covers optimization problems for multiagent systems, explaining distributed solutions to path-planning problems, Markov Decision Problems and scheduling problems. Chapter 2 concludes with a discussion of coordination via social laws and conventions. This is likely to be of particular interest to philosophers and epistemic logicians insofar as conventions and common knowledge are of great concern to both communities. The sketch of conventions given in Chapter 2 is elaborated upon in later chapters.

Block two, from chapters 3 to 6, presents noncooperative game theory, a domain that introduces the notions of competition and cooperation in a multiagent system. This set of chapters includes both normal and extensive-forms of noncooperative games. Specifically, chapter 4 concerns specific approaches to the normal-form. Chapter 7 focuses on learning algorithms using an approach founded both on computer science and game theory. Chapter 8 can also be read independently from the others. It concerns communication between agents in a game-theoretic setting and also from the point of view of linguistics. Chapters 9, 10 and 11 form a coherent block discussing several protocols for groups of agents. The first of this set is related to social-choice theory, such as voting methods. Social-choice theory proposes solutions to the problem of how to aggregate agents preferences. The next chapter concerns mechanism design, that includes a central designer in charge of aggregating the agents preferences. The last chapter of this block is dedicated to the specific case of auctions protocols for groups of agents.

Chapter 12 concerns coalitional game theory. Chapters 13 and 14 are grouped in block seven, concerning logical theories. The first of these covers epistemic logic. The coverage of epistemic logic will be disappointing to philosophers, but is a fair sketch of the main developments in computer science and related areas. Finally, chapter 14 concludes with the discussion of how belief change, which includes an interesting, but unsatisfying discussion of how an agent’s intentions might be formalized.
These blocks follow a logical flow but are independent, allowing its coherent presentation in classroom, with the single exception of blocks 3, 4 and 5 that depend on some elements of noncooperative game theory. The material used along the book, both for theoretical statements and to describe examples, is Bayesian and algorithmic. The understanding of this material requires background knowledge of logic, probability theory, utility theory, algorithms, Markov decision problems (MDPs), and linear/integer programming. These topics are briefly summarized in appendices, but significant levels of additional support and materials will be necessary for most beginning graduate students.

The Web site http://www.masfoundations.org includes diversified instructional resources, such as slides and exercises. However, when this review was written, early June 2009, some of the chapters were not covered yet.

To summarize, in our opinion the book brings together some important foundations of artificial intelligence, epistemic logic, distributed systems and computer science, joined by particular contributions from macroeconomics, and operations research. The result is a clear and broad approach of multiagent systems main issues, such as distributed problem solving, cooperation, learning, communication protocols or coalitions, always in the light of distributed algorithmic, game theory and logic representations. This book is an excellent resource for both students and instructors, and also a useful handbook for researchers in multiagent related domains.