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Sascha Ossowski

Co-ordination in Artificial Agent Societies

Social Structures and Its Implications
for Autonomous Problem-Solving Agents



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Für meine Eltern

Para Sandra

Foreword

Advances in Computer Science often arise from new ideas and concepts, that prove to be advantageous for the design of complex software systems. The conception of multi-agent systems is particularly attractive, as it promises *modularity* based on the conceptual speciality of an agent, as well as *flexibility* in their integration through appropriate interaction models. While early systems drew upon co-operative agents, recent developments have realised the importance of the notion of autonomy in the design of agent-based applications. The emergence of systems of autonomous problem-solving agents paves the way for complex Artificial Intelligence applications that allow for *scalability* and at the same time foster the *reusability* of their components.

In consequence, an intelligent multi-agent application can be seen as a collection of autonomous agents, usually specialised in different tasks, together with a social model of their interactions. This approach implies a dynamic generation of complex relational structures, that agents need to be knowledgeable of in order to successfully achieve their goals. Therefore, a multi-agent system designer needs to think carefully about conceptualisation, representation and enactment of the different types of knowledge that its agents rely on, for individual problem solving as well as for mutual co-ordination. A *knowledge-oriented* approach to agent system design will promote the emergence of methodologies and tools for building multi-agent applications, thereby providing evidence for the added value that agent technology provides over traditional approaches to the design of intelligent software systems.

The proposal that Sascha Ossowski presents in this book applies the above paradigm to artificial agent societies. A comprehensive survey of the different approaches to co-ordination in societies of (human and artificial) agents is given first. Setting out from a critical analysis of the state of the art, he suggests structuring multi-agent applications in line with a mechanism that he calls Structural Co-operation. Agents are provided with expertise about their environment in order to detect and overcome specific types of problem situations, make use of their social knowledge to mutually adjust their activities, and are coerced towards a coherent collective behaviour through normative rules. The proposed model is formalised theoretically within Game Theory, realised practically by means of an agent architecture, and assessed experimentally by building a prototype of a distributed decision support system for road traffic management and comparing it to an alternative model based on a centralised architecture.

The present work is particularly interesting, as it not only promotes a well-founded formal model of co-ordination in artificial agent societies, but also puts it into practice by means of an operational software architecture, organised as a society of intelligent agents, so as to attack an important real-world problem. In spite of focusing on a particular class of domains and settings, the book constitutes a significant contribution, as it proves the feasibility – in design and operation – of building intelligent software applications as artificial agent societies. The societies of autonomous problem-solving agents, that the book advocates for, are an important step towards a modern approach to intelligent system design, where advanced applications coping with complex tasks are configured out of libraries of reusable autonomous agents on the basis of coercive interaction patterns.

In our group, we are happy to have contributed to the research reported in this book. The reader will encounter interesting new ideas that are likely to find their way into future design methodologies for agent-based intelligent systems.

Madrid, September 1998

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Preface

In recent years the interest in agent technology – and agent-related publications – has risen enormously. There are books covering a wide range of recent research in the field: it is easy to find publications on particular agent theories and their underlying logics, on specific agent architectures and their dynamics, as well as on certain agent languages, their syntax and semantics. Although this huge amount of specialised publications makes available a large body of valuable knowledge and research experience, it may also appear unstructured and rather abstract to the reader. It becomes increasingly hard for an engineer to bridge the gap between particular theories, architectures or languages and their application to real-world problems.

This book is concerned with a broad and, as I believe, essential aspect of agent technology: how to achieve instrumental, co-ordinated behaviour among artificial agents for real-world applications? In the attempt to give an answer to this question, it has been necessary to draw on quite different strands of research. However, having in mind the aforementioned arguments, I have tried to pay special attention to show how these pieces fit together.

The book focuses on the nexus between theory and practice in multi-agent system research: setting out from a class of problems, it covers the whole process from the development of a multi-agent theory to the design of a multi-agent application. It reports how notions rooted in sociology can be adapted and transferred to societies of *artificial* agents; how they can be used to build and formalise a co-ordination mechanism within these societies, and how this mechanism is integrated in an experimental multi-agent system for urban road traffic management.

The history of this book dates back to when I left Germany, endowed with a “Human Capital and Mobility” grant of the European Union, in order to take on a research assistance at the Artificial Intelligence Department of the Technical University of Madrid (UPM). It compiles the essence of four years of research work that I carried out as a member of the Intelligent Systems research group at UPM, and in the course of which I defended my dissertation. During this time I had the chance to meet many people in different parts of the world, who have supported the realisation of my ideas in one or another way. I would like to thank them all. Still, I am particularly grateful...

— to professor José Cuenca, director of the Artificial Intelligence Department of UPM and head of the Intelligent Systems research group, for the attention and the time he dedicated to me. He pushed me to do more than I thought I could. Without him, this book would not have reached its present shape.

— to associate professor Ana García-Serrano, my supervisor during my time at UPM. My esteem for her goes beyond the important contribution she provided for the formation of the work presented in this book. Through all this time, Ana has not just been a “boss”, but also a friend.

— to all colleagues who took the trouble to review draft versions of my work: professor Alfons Crespo (UPV, Spain), professor Yves Demazeau (IMAG, France), professor Manuel Hermenegildo (UPM), assistant professor Josefa Hernández (UPM), associate professor Martín Molina (UPM), Dr. habil. David Pearce (DFKI, Germany), M.Sc. José-Luis Sierra (UPM), associate professor Juan Tejada (UCM, Spain) and many more... Their comments and criticisms did a great job in improving clarity and conciseness of this book. Special thanks to Yves Demazeau and David Pearce for encouraging me to submit the manuscript for publication in the LNAI series of Springer Verlag.

— to all members of the Intelligent Systems research group, for their help with many of the tiresome tasks that have come up in the course of the research that led to this book.

I am particularly indebted to my parents, for their moral and intellectual support. A very special “thank you” is owed to Sandra, for her infinite patience with me and my projects. Without her continuous assistance, encouragement and inspiration this book would not have come to a “happy end”.

Madrid, August 1998

Sascha Ossowski

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