Negotiation and Argumentation in Multi-agent Systems

Fundamentals, Theories, Systems and Applications

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Negotiation is a common, everyday activity that most people use to resolve opposing interests. Businesses negotiate to purchase raw materials and to sell final products. Labor and management negotiate the terms of contracts. Lawyers negotiate to settle legal claims before they go to court. The police negotiate with terrorists to free hostages. Nations negotiate trade agreements and peace accords. Friends negotiate to decide which television programs to watch. The list is endless. Hence, negotiation is not a process reserved only for the skilled diplomat, top salesperson, or ardent advocate for organized labor—it is something that everyone does, almost daily. Although the stakes are not usually as dramatic as peace accords or large corporate mergers, everyone negotiates to resolve problems or disputes.

The negotiation process is fundamentally the same at the personal level as it is at the diplomatic and corporate levels. It is a complex dynamic process. Negotiation requires skills, both behavioural and analytical, to diagnose problems and select appropriate strategies and tactics. It typically involves persuasiveness, eloquence, clever maneuvering, and occasional histrionics. Also, it is a learnable process—most people can improve with a few lessons, a bit of coaching, and some tips on how to do it better. Nevertheless, the core of negotiation is reciprocal offer and counter-offer, argument and counter-argument in an attempt to agree upon outcomes mutually perceived as beneficial.

Multi-agent systems (MAS) represent a relatively new and rapidly expanding area of research and development. MAS are systems composed of software agents that interact to solve problems that are beyond the individual capabilities of each agent. Software agents are elements situated in some environment and capable of flexible autonomous action in order to meet their design objectives. Agent technology is being used to solve real-world problems in a wide variety of commercial and industrial applications, including electronic commerce, electricity networks, business process management, process control, telecommunications, and air traffic control.
Clearly, agents are increasingly acting as elements in complex, distributed communities and need to interact with other agents and with people to fulfill their tasks. This phenomenon has been emphasized by the huge growth and success of the Internet. Conflicts between such agents are inevitable—they are not necessarily bad or good, but they are inevitable. Conflicts occur whenever there are scarce resources, when agents have different interests at stake, or when they try to limit each other’s power to control some situations. Conflict resolution is crucial for avoiding harmful interactions, reconciling disparate viewpoints, and ensuring that agents act coherently in making decisions or taking action. Negotiation is the predominant process for productively managing conflict.

This book is about the common ground between two fields of inquiry: negotiation theory and multi-agent systems. Human negotiation is studied in the various branches of the social sciences, notably economics, international relations, management science, and social psychology. Automated negotiation is an active area of research in artificial intelligence (AI) and computer science generally. This book lets these different strands come together—it includes methods and techniques from the social sciences and AI, merging human with automated negotiation, and thus natural with artificial intelligence.

The area of negotiation in multi-agent systems has grown significantly in the past few years resulting in a substantial body of work and well-established technical literature. There are several journals that focus on research in this area (e.g., Group Decision and Negotiation, and Autonomous Agents and Multi-Agent Systems). In addition, various forums have been dedicated to the study of negotiation in MAS, such as the Group Decision and Negotiation conference series, and the Agent-Based Complex Automated Negotiation (ACAN) workshop series held in conjunction with AAMAS. And development has occurred on the practitioner side as well. At present, automated negotiation systems with software agents representing individuals or organizations and capable of reaching mutually beneficial agreements are beginning to become an important subject of academic teaching, and industrial and commercial applications. Yet, although valuable collections of articles exist, particularly special issue journals and proceedings of conferences and workshops, there is no comprehensive presentation of the major achievements in the area. Also, efforts to draw from the broader study of techniques for influence and argumentation, to integrate this work into a broader understanding of negotiation, or to apply this work to a broad spectrum of conflict and negotiation settings were only beginning to occur. The purpose of this volume is to fulfill these needs.
This book reflects the state of the art in the area of negotiation in MAS, and presents the most recent and very best work on negotiation and the related topics of conflict management and argumentation. It offers the reader a comprehensive and up-to-date overview of the principal theories, methods, and findings relating to the area. The primary audience is composed of researchers, instructors, and graduate students—the book successfully integrates theory, scientific research, and practical applications, and is sufficiently informative to earn the respect of specialists. At the same time, readers who have not specialized in the study of negotiation in MAS should find this an excellent introduction to the area. It is written in a highly accessible style and the text is liberally supported with examples and illustrations.

The book gives an insightful view of a landscape of stimulating ideas and offers a number of key features, notably:

- **Scope.** It is organized into three parts: Fundamentals, Theories and Systems, and Applications. It introduces the reader to the essentials of negotiation in MAS (Part I), treats various specialised topics in detail (Part II), and presents some practical applications (Part III).

- **Theory.** It gives a clear and careful presentation of the key concepts and algorithms that form the core of the area. Many examples and illustrative case studies are provided.

- **Practice.** The emphasis is not only in theory, but also on practice. The ideas presented in the book are supplemented with real-world applications, such as liberalized electricity markets and pervasive services.

- **Expertise:** Its chapters have been written by leading and outstanding authorities that have helped shape the area of negotiation in MAS. This guarantees that the book is built on a very broad and diverse basis of knowledge and experience.

An explanatory and cautionary note about the last-mentioned feature is in order. It is clear that a book prepared by just a few authors is likely to be more coherent than a book in which many authors are involved. But as the reader will see, the editors have invested considerable effort in ensuring the coherence of the book—the chapters’ topics and order was done carefully to produce a highly organised text containing a progressive development of ideas, concepts, and techniques. Also, contributors had the chance to review each others’ work at various stages of writing in order to ensure unified notation (when possible), helping to significantly improve the quality of the book.
This book could not have been completed without the assistance of numerous people. We especially thank:

- All authors of the book, who have shared ideas and deep insights into the fertile area of negotiation in MAS.
- The different organisations that have supported the authors.
- Many of our colleagues working on effective negotiation, who have given us helpful feedback to improve the content of the book.
- The staff of Bentham Science Publishers, for their excellent editorial assistance.
- Our families, who have provided us with the time and support required to finish this project—it is to them that this book is dedicated.

In conclusion, this book is very much a team effort of different people, whose credentials as researchers in the area of negotiation in MAS are impressive, and whose research efforts have made the growth of this area possible.*

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Part I

Fundamentals
Chapter 1
Autonomous Agents and Multi-Agent Systems

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Abstract. The autonomous agents and multi-agent systems domain was very active and fruitful along the last decade, mainly due to the community research efforts, with the organization of more than 50 workshops and a yearly major international conference (AAMAS). Moreover, the domain has reached the 3rd. place in IJCAI 2009 and the 2nd. place in ECAI 2010 in the number of accepted full papers, thus revealing its high relevance within the mainstream current research in the major field of Artificial Intelligence. In this paper, we try to cover its five key elements (agents, environments, interactions, organizations and users), after presenting a brief sketch of its historical milestones. We conclude by pointing out the future aims of research and the right place of negotiation and argumentation within the context of the domain.

Keywords: Agency, Autonomy, Classification Grid, Coalition, Consilience, Decision Theory, Distribution, Game Theory, Governance, Heuristics, Pattern of Cooperation, Social Exchange.

1.1 Introduction

Computing is everywhere. There is now a global and different kind of computing: a massive, globally distributed network of ubiquitous, intelligent knowledge processors, embedded with interlinked smart devices. Unlike the

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Chapter 2
Game Theoretic Models for Strategic Bargaining

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Abstract. Bargaining is one of the most common negotiation situations in which agents must reach an agreement regarding how to distribute objects or a monetary amount. On the one side, each agent prefers to reach an agreement, rather than abstaining from doing so. On the other side, each agent prefers that agreement which most favors her interests. This problem has been widely studied in the game theory literature, under the assumption that agents are *intelligent* (i.e., able to collect all the information over the opponents) and *rational* (i.e., able to maximize their gain). The most satisfactory models represent a bargaining situation as a *non–cooperative (strategic) game*, where a solution is a strategy profile, specifying a strategy per agent, that is somehow in equilibrium. This chapter surveys the game theoretic strategic models for bargaining and the corresponding solving algorithms. Although the bargaining problem has been studied in the literature for almost 30 years, no algorithm able to solve a general bargaining problem with uncertainty is known. The critical issues behind the game theoretic approaches and some possible new research directions are also discussed.

Keywords: Game theory, Bilateral bargaining, Nash equilibrium, Rational agents, Non–cooperative negotiation, Uncertainty, Bayesian models, Alternating–offers protocol, Bargaining in markets, Self–confirming equilibrium.

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Chapter 3
Computational Negotiation

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Abstract. Negotiation is a process of opportunistic interaction by which two or more parties seek a solution for a divergence of interests through jointly decided action. Traditional negotiation, conducted face-to-face and via telephone or mail, is a critically important activity in all realms of human interaction and often proceeds through several distinct phases or stages—notably a beginning or initiation phase, a middle or problem-solving phase, and an ending or resolution phase. Automated negotiation, conducted autonomously by software agents representing individuals or organizations, is an active area of research in artificial intelligence and computer science generally. Increasingly, automated negotiation systems help in achieving efficient agreements—examples, to mention a few, include the business trend toward agent-based supply chain management, the pivotal role that electronic commerce is increasingly assuming in many organizations, and the industrial trend toward virtual enterprises. This chapter discusses and analyses some of the key negotiation techniques for software agents, placing emphasis on both the early stages of negotiation and the process of moving toward agreement.

Keywords: Intelligent software agents, Multi-agent systems, Automated negotiation, Pre-negotiation, Bargaining, Protocols, Strategies, Preferences, Negotiation Frameworks, Negotiation Systems.
Chapter 4
Advances in Argumentation-based Negotiation

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Abstract. Argumentation-based negotiation (ABN) is a prevailing approach for automated negotiation. It is based on the exchange of arguments that allow an agent to acquire additional information about the other agents and the particular circumstances of the negotiation, and can be used for attacking or justifying offers. This is an important element in resolving conflicts that very often are due to the assumptions agents have made when making decisions and which may be found to be false in the course of the negotiation. Argumentation-based negotiation can be characterized in terms of three main topics, namely a) the reasoning mechanisms the agents use for negotiating and which are based on argumentation, b) the protocols the agents use for conveying arguments and offers and, c) the strategies that determine their choices at each step of the negotiation. This chapter presents argumentation-based negotiation by discussing representative works dealing with these three topics.


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Part II

Theories and Systems
Chapter 5
An Overview of Argumentation-Based Negotiation Theory and Decision Support Systems

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Abstract. In this chapter, we provide a multi-disciplinary perspective of the theory and decision support systems of argumentation-based negotiation. Based on an extensive discussion of limitations of proposal-based argumentation, we emphasize the central role of persuasive arguments in a negotiation. Then we draw insights from three theoretical perspectives of argumentation-based negotiation research: argumentation-based automated negotiation, argumentation games, and cheap-talk games. Our reflection on the extant literature leads to a conceptual framework for decision support systems, which consists of key functionality and system components. We also discuss open issues and challenges in the development of the theory and systems of argumentation-based negotiation.

Keywords: Argumentation-based negotiation, Decision support systems, Role of argumentation in negotiation, Rationality framework, Cheap-talk games, Persuasive arguments, Emotion in negotiation, Opponent belief, Negotiation system design, Implementation of negotiation theory.

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Fernando Lopes (Ed.) and Helder Coelho (Co-Ed.)
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Chapter 6
Formal Analysis of Negotiation Protocols for Task Allocation

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\textbf{Abstract.} To formally understand the complex behaviors of negotiating agents so as to design appropriate mechanisms to approximate optimal performance, we have constructed a unified framework to model and analyze the task allocation problem in agent societies with different objectives. This OAR framework includes three aspects: agent’s objective (O), its negotiation attitude (A) and the reward splitting (R) among agents who cooperate to accomplish tasks. An agent’s objective can span the spectrum from totally self-interested to completely cooperative, and there can be a mixture of agents with varying objectives in one agent society. This work focuses on understanding how these different aspects interact in order to achieve individual agent’s objective and to produce effective system

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Chapter 7
Argumentation and Artifacts for Negotiation Support

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Abstract. Negotiation is a central process in an agent society where autonomous agents have to cooperate in order to resolve conflicting interests and yet compete to divide limited resources. A direct dialogical exchange of information between agents usually leads to competitive forms of negotiation where the most powerful agents win. Alternatively, an intelligent mediated interaction may better achieve the goal of reaching a common agreement and supporting cooperative negotiation. In both cases argumentation is the reference framework to rationally manage conflicting knowledge or objectives, a framework which provides the fundamental abstraction “argument” to exchange pieces of information. In this paper we present a novel conceptual framework for negotiation dialogues using argumentation between autonomous software agents which enables their dialogues to be automated. The framework, called SANA (Supporting Artifacts for Negotiation with Argumentation), incorporates intelligent components able to assist the agent participants to reach agreement by inferring mutually-acceptable proposals. The framework also permits agents to engage in negotiation dialogues with each other, generating and exchanging proposed deals and arguments for and against these proposals. Acceptability of

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Chapter 8
RANA: a Relationship-aware Negotiation Agent

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Abstract. Much has been written on the use of rhetorical argumentation to alter the beliefs of a partner agent within a particular negotiation. The problem addressed in this chapter is the measurement of the long-term value of rhetorical argumentation in repeated interactions between a pair of agents, and of the management of such argumentation to achieve strategic aims concerning the strength of the agents’ relationships. RANA is a relationship-aware negotiation agent in the context of information-based agents \cite{1} that have embedded tools from information theory enabling them to measure and manage strategic information.

Keywords: Argumentation, Negotiation, Bargaining, Social relationships, Information theory, Rhetorics, Trust, Software Agent, Agent architecture, Multi-agent System.

8.1 Introduction

Human agents generally place great value on their relationships with others particularly in the conduct of business \cite{2, 3}. Business relationships develop as a subtle byproduct of interaction. Our premiss is that if artificial agents are to conduct business automatically then they too will need to understand the value of business relationships, and will need tools to build and manage

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Chapter 9
Normative and Trust-based Systems as Enabler Technologies for Automated Negotiation

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Abstract. In this chapter we elaborate on the specification and exploitation of a software agent-based Electronic Institution, embedding both a Normative Environment and a Computational Trust service which, when used in tandem, lead to an enhanced process of selection of potential business partners and enable automatic contract negotiation. We introduce a formalization of a Normative Environment, which accommodates the establishment of e-contracts and provides a contract monitoring facility. Contracts are established and enacted by contractual partners previously selected through an automatic negotiation process. While monitoring contracts at run-time, the Normative Environment makes use of a reporting mechanism to inform relevant contract enactment events to interested parties. In our work, we benefit from this reporting function by exploiting it as an input to a computational trust mechanism. We also present the built-in Computational Trust service, a key element of the Electronic Institution. This service includes two main components: the Contractual Evidences Manager, which generates contractual evidences from contract enactment events; and the Trust Aggregation Engine, a situation-aware trust aggregator that takes into account properties of the dynamics of trust and the contractual context under assessment. We then discuss and propose

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Part III

Applications
Chapter 10
Multiattribute Bilateral Negotiation in a Logic-based E-marketplace

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Abstract. In this chapter we present an application and a framework aiming at the automation of bilateral negotiation on multiple issue in e-markets. We address several challenges of a typical negotiation in an online marketplace, such as (i) how to elicit preferences from users; (ii) how to formally represent preferences that at the same time allow human users to express both qualitative and quantitative preferences; (iii) how to compute agreements which are mutual beneficial for both buyer and seller, i.e., outcome enjoying economics properties as Pareto-efficiency. The issue of preference elicitation is addressed with the help of an easy-to-use graphical interface hiding all the technicalities of the underlying framework. Preferences are then mapped to a logic language, that allows one to express preferences on both numerical and non-numerical features. We build a utility function on top of this logic language in order to permit the representation of relative importance among preferences, to evaluate the possible agreements and finally choose the one(s) enjoying the Pareto-efficiency property.

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Chapter 11
Multi-Agent Negotiation for Coalition Formation and Management in Electricity Markets

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Abstract. Negotiation is a fundamental tool for reaching understandings that allow each involved party to gain an advantage for themselves by the end of the process. In recent years, with the increasing of competitiveness in most sectors, negotiation procedures become present in practically all of them. One particular environment in which the competitiveness has been increasing exponentially is the electricity markets sector. This work is directed to the study of electricity markets’ participating entities interaction, namely in what concerns the formation, management and operation of aggregating entities—Virtual Power Players (VPPs). VPPs are responsible for managing coalitions of market players with small market negotiating influence, which take strategic advantage in entering such aggregations, to increase their negotiating power. This chapter presents a negotiation method to create and manage players’ coalitions. This approach is tested using MASCEM, using this simulator’s capability of providing an adequate framework to model and simulate VPPs. VPPs represent agents’ coalitions, capable of negotiating in the electricity market, and internally, with their members, combining and managing their individual characteristics and specific goals, with the objectives and strategy of the VPP itself.

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Abstract. Research in Multi-Agent Planning (MAP) has traditionally been concerned with the design of coordination mechanisms such that the resulting joint plan meets the global goals of a problem. In contrast to most MAP techniques, in this paper we present a novel argumentation-based approach for multiple agents that plan cooperatively while having different capabilities, knowledge about the world and even contradictory information. Our aim is to enhance the role of argumentation as a means to attain a collective behaviour when devising a joint plan. Since agents’ decisions are influenced by the other agents’ plans, the use of mechanisms becomes relevant for persuading an agent to adopt a certain course of action, or negotiating on the use of scarce resources. Through a dialectical process, agents will discuss the different choices put forward by the others thus reaching a commonly agreed solution plan.

Keywords: Multi-agent Systems, Argumentation, Planning, Multi-agent Planning, Coordination, Argument schemes, Dialectical trees, Intelligent Agents, Computational Argumentation, Argumentation-based Negotiation.

12.1 Introduction

Planning is the art of building control algorithms that synthesize a course of action to achieve a desired set of goals. The mainstream in practical planning
Chapter 13
Argumentation-based Conflict Resolution in Pervasive Services

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Abstract. Pervasive services applications often employ networked sensors, devices and appliances to build intelligent and adaptable environments, such as Smart Homes. One of the most significant emergent problems in the deployment of such applications is conflicting sensors information. The system is required to decipher the true context of ambiguous or conflicting data in order to efficiently assimilate context-awareness and subsequently ensure accurate adaptability to suit the application space. To-date, there has been speculation as to the optimal method to disambiguate conflicting data; citing the use of “argumentation” based reasoning to resolve conflict situations as a theoretical solution. This chapter presents the first known implementation of argumentation based conflict resolution for pervasive services computing. It proves that the concept is feasible, accurate and efficient, through simulated deployment on a range of conflict scenarios. The prototype is based on SOA4D built upon the OSGi platform and implements DPWS; and is capable of resolving conflicting data gathered from up to 10 sensors in approximately 2.5 seconds. In effect, this work realises the potential of argumentation theory to solve real-world problems in services computing.

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