A Negotiation Model for Autonomous Agents: Key Features and Comparison with Existing Models

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ABSTRACT

This paper presents the key features of a new negotiation model for autonomous agents. The model is generic, handles multi-party and multi-issue negotiation, acknowledges the role of conflict as a driving force of negotiation, formalizes a set of human negotiation procedures, allows the dynamic addition and removal of issues, and accounts for a tight integration of the individual capability of planning and the social capability of negotiation. This paper also characterizes the model along a set of dimensions and compares it with other developed models.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence—*Intelligent agents, Coherence and co-ordination.*

General Terms

Theory, Algorithms, Design, Experimentation.

Keywords

Autonomous agents, conflict of interests, negotiation.

1. INTRODUCTION

Autonomous agents are being used in an increasing number of applications. The agents operate in complex environments and, over time, conflicts inevitably occur among them. The predominant process for resolving conflicts is negotiation. This paper presents the key features of a new negotiation model for autonomous agents, characterizes the model along a set of dimensions, and compares it with other developed models.

This paper builds on our previous work in the area of negotiation. Lopes et al. [3] describe the model and present an experiment conducted to assess the feasibility of building autonomous negotiating agents equipped with a simplified version of the model. Lopes et al. [4] extend the model by introducing a number of negotiation strategies based on human procedures typical of integrative negotiation.

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2. KEY FEATURES OF THE MODEL

The model is generic and handles multi-party and multi-issue negotiation. The main components of the model are: (i) a pre-negotiation model, (ii) a multilateral negotiation protocol, (iii) an individual model of the negotiation process, (iv) a set of negotiation strategies, and (v) a set of negotiation tactics. The model exhibits the following key features:

- acknowledges the inevitability of conflict among agents operating in a common environment and exploits the presence of conflict to drive negotiation; specifically, exploits the presence of conflict to formulate the negotiation problem;
- formalizes the key activities that human negotiators often perform before starting to negotiate; furthermore, defines a structure for the problem under negotiation and makes use of that structure to define both the set of issues and the set of initial proposals;
- formalizes important strategies used by human negotiators; moreover, defines the strategies by computationally tractable functions;
- supports problem restructuring, *i.e.*, the dynamic change of the structure of the problem under negotiation; problem restructuring allows the addition and removal of issues during the course of negotiation and, as a result, increases the parties' willingness to compromise and facilitates the resolution of deadlocks;
- accounts for a tight integration of individual and social behavior; in particular, accounts for a tight integration of the individual capability of planning and the social capability of negotiation.

3. RELATED WORK

The design of autonomous agents with negotiation competence has been investigated from both a theoretical and a practical perspective. Researchers following the theoretical perspective attempt mainly to develop formal models. Some researchers define the modalities of the mental state of the agents, develop a logical model of individual behavior, and then use the model as a basis for the development of a formal model of negotiation or argumentation. However, most researchers are neutral with respect to the modalities of the mental state and just develop formal models of negotiation. These models are often based on game-theoretic techniques. Generally speaking, most theoretical models are rich but restrictive. They make assumptions that severely limit their applicability to solve real problems.

Researchers following the practical perspective attempt mainly to develop computational models, *i.e.*, models defining the key data structures of the agents and the processes operating on these structures. Some researchers start with a model of individual behavior, develop or adopt a negotiation model, and then integrate both models into a unified model that accounts for individual and social behavior (e.g., [6]). However, most researchers prefer to be neutral about the model of individual behavior and just develop negotiation models (e.g., [1]). Broadly speaking, most computational models are based on realistic assumptions and use moderate computational resources, but lack a rigorous theoretical underpinning and lead to outcomes that are sub-optimal.

As noted, both the theoretical and the practical perspectives have specific strengths and weaknesses. However, despite the weaknesses of the practical perspective, an increasing number of researchers believe that it is necessary to develop computational models in order to successfully use autonomous agents in real-world applications. Also, as noted, most researchers following the practical perspective have been neutral with respect to the model of individual behavior and focused solely on developing negotiation models. This design philosophy allows the adoption of any model of individual behavior. However, it raises the problem of integrating a particular model of individual behavior with negotiation models. It is one of the commonest and costliest lessons of computer science that independently developed components resist subsequent integration in a smoothly functioning whole. Accordingly, this work introduces a computational model that accounts for a tight integration of the individual capability of planning and the social capability of negotiation.

Artificial Intelligence (AI) researchers have developed a number of computational models of negotiation to date. Generally speaking, they do not traditionally have acknowledged and explored the role of conflict as a driving force of negotiation. Also, they have been more inclined to take action, *i.e.*, to understand and formalize the bidding process, than to think about effective preparation and planning for negotiation. In addition, they have paid little or no attention to important strategies used by human negotiators (e.g., logrolling and compensation). Finally, as stated, they have paid very little attention to the issues involved in developing integrated models.

Figure 1 summarizes the key features of five representative models along a set of dimensions. The models handle two-party or multi-party negotiation (dimension 1). Two models explore the presence of conflict to drive negotiation (dimension 2). One model accounts for systematic preparation and planning for negotiation (dimension 3). Surprisingly, no model incorporates a clear definition of the problem under negotiation nor allows the direct identification of the issues (dimension 4). One model defines a (simple) way for manipulating the set of issues (dimension 5). Some models handle only cooperative behaviour and other models handle cooperative and competitive behaviour (dimension 6). One model accounts for the integration of individual and social behaviour (dimension 7). Finally, one model adopts negotiation procedures from economics (dimension 8).

Figure 1 also summarizes the key features of our negotiation model and compares it with the other models. Our model handles multi-party and multi-issue negotiation, acknowledges and explores the role of conflict as a driving force of negotiation, incorporates the key activities that human negotiators often perform before starting to negotiate, formalizes the problem under negotiation and allows the direct identification of the negotiation issues, supports problem restructuring, handles a number of negotiation behaviors, accounts for a tight integration of individual and social behavior, and adopts a set of negotiation procedures from management and social psychology.

	Susan Lander [2]	Jörg Müller [6]	Zeng and Sycara [7]	Maes et. al [5]	Peyman Faratin [1]	Lopes et al. [3, 4]
1. Number of Parts	*n*	*n*	*n*	*n*	2	*n*
2. Conflict of Interests (detection and exploration)	yes	yes	no	no	no	yes
3. Pre-Negotiation (preparation and planning)	no	yes	no	no	no	yes
4. Problem Definition and Issue Identification	no	no	no	no	no	yes
5. Problem Restructuring (addition/removal of issues)	no	no	no	no	yes	yes
6. Negotiation Behaviour (cooperative – competitive)	coop.	coop.	coop. & comp.	coop. & comp.	coop. & comp.	coop. & comp.
7. Integration of Individual and Social Behaviour	no	yes	no	no	no	yes
8. Adoption of Strategies from the Social Sciences	no	no	no	no	yes	yes

Figure 1: Comparison of our work with related work

To conclude, this work extends the state of the art in automated negotiation by presenting a new model for autonomous agents that handles multi-party and multi-issue negotiation and exhibits the key features mentioned above.

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