On Efficient Mediation Approach to Multi-issue Negotiation with Optimal and Fair Outcomes

(Extended Abstract)

Minyi Li
Swinburne University of Technology
John Street, Hawthorn, Australia
myli@swin.edu.au

ABSTRACT

Empirical evidence suggests that self-interested agents often fail to reach optimal agreements in multi-issue negotiations. Most existing negotiation approaches either do not address fairness issues; or do not consider computational concerns. To address these problems, the aim of this research is to investigate negotiation techniques, introducing efficient mediation approaches to support multi-issue, multi-agent negotiations with optimal and fair outcomes under incomplete information setting.

Categories and Subject Descriptors

I.2.11 [**Distributed Artificial Intelligence**]: Multiagent Systems; K.4.4 [**Computers and Society**]: Electronic Commerce

General Terms

Algorithms, Design, Theory

Keywords

automated negotiation, Pareto-efficiency, fairness, preference, mediator

1. INTRODUCTION

Multi-issue negotiation is a fundamental interaction mechanism in multi-agent systems. However, empirical evidence suggests that self-interested agents often end up with inefficient results in multi-issue negotiations [6]. To summarize, multi-issue negotiation is complex and challenging because of the following reasons. *i*) Complex preference: the outcome space is m-dimensional and the agents' preference over multiple issues are complex. *ii*) Incomplete information: agents' preferences are not common knowledge. *iii*) High computational complexity: the burden of computation and reasoning about the negotiation strategies in multi-issues negotiation is high. Most existing negotiation approaches with incomplete information either do not address fairness issues; or do not consider computational concerns.

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To address the above challenges, the aim of this research is to investigate negotiation techniques, introducing efficient mediated negotiation approaches to support multi-issue, multi-agent negotiations with fair and optimal outcomes under incomplete information. By optimal solution, I refer to a solution that is *Pareto-optimal*. Another desirable property considering fairness would be to ask for an optimal outcome maximizing the well-being of the worst-off agent, called the *egalitarianism social welfare*. Some topics that I study in my thesis include: efficiency and fairness of a negotiated outcome, mediation approaches for utility-based negotiation over continuous issues, discrete issues and qualitative preferences, mediation approaches for negotiation with qualitative preferences, computational complexity of the negotiation mechanism.

2. RELATED WORK

2.1 Multi-issue negotiation with utility functions

Most of the existing works have been dealing with the utility-based negotiation problems. For instance, Ehtamo et al. [2] present a mediation-based negotiation framework for making trade-offs, while also creating joint utility gains for the negotiating agents. However, their proposed approach leaves the fairness issue between the agents' utility gains largely unanswered. Another mediated negotiation model with incomplete information is given by Lai et al. [3]. In their approach, the mediator conducts a Pareto efficient enhancement for a proposal in each negotiation period. However, their proposed approach is not necessarily feasible and does not guarantee Pareto optimality [5].

2.2 Qualitative preference on discrete issues and collective decision making

It is well recognized that utility-based preference elicitation is complicated and typical users may not be able to provide much more than qualitative rankings of outcomes [1]. In my thesis, I investigate the theory of CP-net (Conditional Preference Network) [1] as a formal model for representing and reasoning with the negotiation agents' preference over discrete issues. The motivation of applying CP-nets in negotiation scenarios is that, CP-net specifies individual preference relations in a relatively compact, intuitive, and structured manner, and thus enables us to easily encode human preferences and highly supports the negotiation systems in real world applications.

Most existing works on CP-net focus on individual preference reasoning (for example, see [1]), however, negotiation involves multiple agents and the agents' preferences are not common knowledge. Rossi *et al.* [7] define a multi-agent extension to CP-nets and propose various voting semantics for aggregating multiple agents' CP-nets, but they do not consider computational concerns. Lang [4] addresses the decompositions with a voting rule based on the assumption that all the agents share a common preferential independence structure. However, it is a demanding assumption that is unlikely to be met in practice. Furthermore, the above works generally assume that perfect information of the agents' CP-nets are available, which is particularly hard to be applicable in the negotiation scenarios.

3. SOLUTION APPROACH

In my thesis, I separate out the negotiation problems over continuous issues from those over discrete issues, investigate appropriate preference representation models for different type of issues, analyse the system goals of the negotiation problem with different type of preferences, and propose the appropriate mediation techniques to deal with the negotiation problems with different type of preferences respectively.

3.1 Negotiation over continuous issues

For the type of continuous issues, I consider the classical negotiation theory that mathematically represents agents' preferences by utility functions. I propose a new mediated negotiation approach to support multiple agents reaching a Pareto optimal and fair agreement over multiple continuous issues under incomplete information. The proposed approach uses a non-bias mediator as a tool for step-by-step creation of fair joint gains. At each stage of negotiation, the mediator searches for the compromise direction based on the solution to a mathematical programming problem, called the DMP (Deviation Minimization Problem). The objective of this approach is to find more efficient outcomes, which improve all the agents' utilities while minimizing the difference between the agents' utility gains, leading to fair agreements. I experimentally evaluate the proposed approach. The experimental results demonstrate that the proposed approach not only guarantees Pareto optimality, but also produces the outcomes that are close to the fair Egalitarian solution.

3.2 Negotiation over discrete issues

For the type of discrete issues, I study the negotiation problem in the case where the agents have structural preferences represented by CP-nets. The major issues that I plan to solve in my thesis includes: *i)*formalizing Pareto-optimality and fairness with CP-nets; *ii)*developing an efficient negotiation mechanism enabling trade-offs between issues, and guaranteeing optimal and fair agreements for rational agents; *iii)*analysing the computational complexity of the negotiation mechanism.

I first study the collective decision making problem with complete information and propose a Majority-rule-based outcome selection method to compute the majority winner efficiently. Removing the assumption of complete information, I'm now studying the problem of negotiation with CP-nets under incomplete information. I develop an efficient negotiation approach, called `MNCP`, which enables multiple agents to negotiate and trade-off between issues. I apply the *Rank semantics* [7] to measure the quality of an outcome for a given agent. Given a CP-net of an individual agent, the rank of an outcome is the shortest distance between the optimal outcome and that outcome in the corresponding induced preference graph of the given CP-net. Based on ranking semantics, I argue that the goal of the negotiation procedure should be to produce *Pareto optimal* agreements that *minimize the maximum rank of the negotiating agents*. It has been experimentally evaluated that the proposed approach heuristically reduces the size of the search space and is computationally efficient. Furthermore, I'm now working on some theoretical results regarding optimality and fairness of the proposed `MNCP` approach.

4. FUTURE WORK PLAN

During the next 8 months (2010.02 - 2010.10) of my PhD, the main focus is on mediated negotiation with qualitative preference (i.e. CP-nets and its extensions). After I complete the research work on negotiation with CP-nets, I will explore more powerful variants such as TCP-nets for representing agents' preferences in negotiation. I believe they can be similarly applied to support more expressive preferential semantics on preference trade-offs such as relative importance and conditional relative importance. During the final six months (2010.10 - 2011.04), the PhD thesis which enhances and summaries my entire work will be completed.

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6. REFERENCES

[1] C. Boutilier, R. I. Brafman, H. H. Hoos, and D. Poole. CP-nets: A tool for representing and reasoning with conditional ceteris paribus preference statements. *Journal of Artificial Intelligence Research*, 21:135–191, 2004.

[2] H. Ehtamo, E. Kettunen, and R. Hamalainen. Searching for joint gains in multi-party negotiations. *European Journal of Operational Research*, 127(1):54–69, April 2001.

[3] G. Lai, C. Li, and K. Sycara. Efficient multi-attribute negotiation with incomplete information. *Group Decision and Negotiation*, 15:511–528, 2006.

[4] J. Lang and L. Xia. Sequential composition of voting rules in multi-issue domains. *Mathematical Social Sciences*, 57(3):304–324, May 2009.

[5] M. Li, Q. B. Vo, and R. Kowalczyk. Searching for fair joint gains in agent-based negotiation. In *AAMAS '09: Proceedings of The 8th International Conference on Autonomous Agents and Multiagent Systems*, pages 1049–1056, Richland, SC, 2009. International Foundation for Autonomous Agents and Multiagent Systems.

[6] H. Raiffa. *The Art and Science of Negotiation*. Harvard University Press, Cambridge, USA, 1982.

[7] F. Rossi, K. B. Venable, and T. Walsh. mCP nets: Representing and reasoning with preferences of multiple agents. In D. L. McGuinness and G. Ferguson, editors, *AAAI*, pages 729–734. AAAI Press / The MIT Press, 2004.