AutoMed - An Automated Mediator for Bilateral Negotiations Under Time Constraints

Michal Chalamish and Sarit Kraus
Bar-Ilan University
Department of Computer Science
Ramat-Gan 52900, Israel
{merlich,sarit}@cs.biu.ac.il

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence —*Multiagent systems*

General Terms

Experimentation

Keywords

Automatic mediation, Mediation tools, Negotiation

1. INTRODUCTION

Engaging in negotiations is a daily activity. Some negotiations require the involvement of a mediator in order to be concluded in a satisfying manner. In such cases, the objective is to help the negotiators reach a mutually beneficial agreement [6, 4]. Our research focuses on mediation tools for dealing with bilateral negotiations under time constraints.

The dispute itself consists of multiple issues and multiple values for each issue. The negotiators need to agree on a single value for each issue, while their preferences are naturally different. This type of disputes must be resolved by implementing a trade off between the issues, which makes the negotiation, as well as the mediation, more complex than most human-computer negotiations dealt with until now (e.g. [5]).

A negotiation can end either by reaching an agreement, by one of the negotiators opting out and enforcing the continuous of the status quo or by reaching the deadline and inflicting the status quo on issues not yet resolved. Infliction of the status quo most probably will not resolve the dispute.

The following assumptions are made concerning the negotiation dealt with:

- The negotiators know only their own preferences over the solution possibilities.
- There might be high costs for both parties or at least one. Costs might rise with time and there exists a deadline by which the negotiation must end.
- At least one agreement is preferred by both parties over opting out or exceeding the deadline.

These assumptions are valid in dispute domains such as e-commerce, working contracts fulfilment differences etc'.

A human mediator is not always available. Online Dispute Resolution (ODR) [2] tools can be used. In many cases, an automated mediator , which is completely confidential and non-biased can also be an option. There have been several attempts at creating automated mediators. Some, such as [10], act as support systems. Others are topic embedded, as are [1] and [9].

Most negotiating systems use a quantitative preference representation model, mainly utility functions [7], which are ideal for reasoning with user preferences in quantitative environments. Unfortunately, many real-world situations are not suitable for such modeling, especially in situations which might include possible loss of lives or serious injuries, in which the association of numerical values to solution possibilities is very difficult.

This paper presents AutoMed, an automated mediator for bilateral negotiation under time constraints which uses a *qualitative* model, reviewed in section 2.1, for negotiators' preferences representation. AutoMed, introduced in section 2, can be used for every bilateral dispute meeting our assumptions. Both parties specify their preferences, while AutoMed analyzes the data, monitors the negotiations and proposes solutions to the negotiators.

Our experiments, presented in section 3, show that negotiations mediated by AutoMed are concluded significantly faster than non-mediated ones. They also show that all the negotiations mediated by AutoMed were concluded with agreements, while some of the non-mediated ones ended when reaching the time limit or with one side opting out. The satisfaction level was also higher among the mediated negotiation participants. We conclude by reviewing related work in section 4 and future work in section 5.

2. AUTOMED

AutoMed first elicits the negotiators preferences using *WCP networks*, an enhanced version of CP networks defined below. Each disputant specifies her preferences by creating her WCP net using a graphical interface. The WCP nets are kept confidential.

Next, AutoMed *orders all possible agreements* according to the WCP nets. It then decides wheatear to *intervene* in the negotiation and *suggest an agreement* currently believed to be the best.

AAMAS'07 May 14–18 2007, Honolulu, Hawai'i, USA.

2.1 WCP-networks

A *conditional preference* (CP) network is a user preferences representation model. It consists of a graph describing the preferential dependency relations between all the issues defined in a certain domain. The preferences over the values defined for each issue are annotated by a conditional preference table (CPT). See [3] for a full definition.

AutoMed uses an enhancement of this model. It needs to maximize the satisfaction of two users instead of one, as CP nets are intended for. A CP net is used to determine if one outcome o_1 is preferred over another o_2 by a given user. In our case, knowing that o_1 is preferred over o_2 according to one negotiator and o_2 is preferred over o_1 by the second is not enough. AutoMed must decide which of the two to suggest, or possibly o_3. This task requires further information. The CP net definition is enhanced to add the property of importance by using the *weighted importance* table (WIT), so allowing the association of a numerical value to each outcome. The extended model will be referred to as Weighted CP Networks (WCP networks).

An *agreement* is an assignment of values to all issues. In a *partial agreement* not all issues are assigned a value. The unassigned values will be annotated with the empty value ε. For example, $o = a\varepsilon\bar{c}\bar{d}\varepsilon fg$ is a partial agreement where no values are assigned to B and E.

2.2 Negotiation protocol

The negotiation protocol allows each negotiator to propose agreements to the other side. An offer can include "not in discussion" values, making it a partial offer. The opponent can either accept or offer a different agreement. A value already accepted by both can be changed by agreeing upon another. Agreed upon issues are accumulated to achieve a full agreement. AutoMed's proposals are always full and are sent to both parties simultaneously. If both accept its offer, an agreement is reached.

2.3 Ordering possible agreements

ML ordering defined by Rossi et. al. [8] compares attributes according to their levels in the graph, we enhance that to take weighted importance into consideration. We call this ordering *weighted* ML ordering (WML ordering). Formally, let $riw(A)$ be the relative importance weight defined for A. If no such value is defined then $riw(A) = 1$. Let $ml(A)$ be the level assigned to A by the ML ordering. Using the ML ordering means that the outcome's issues are summed up according to their values. If $a \succ \bar{a}$, for the assignment of a the outcome gets 1 and for the assignment of $\bar{a}$ it gets 0. Comparison of the summation determines which outcome dominates the other, or declares a tie. The definition of the WML ordering proposes to sum up the multiplication of the value with the importance weight. If $a \succ \bar{a}$, then for the assignment of a the outcome gets $riw(A)$ and for the assignment of $\bar{a}$ it gets 0.

2.4 Suggesting a possible agreement

AutoMed's main task during the negotiation is to propose the right agreement. AutoMed should also decide when to propose its own solution in a way that will contribute to the negotiation and not interfere it.

Our method is two-fold. The first part is calculated after both sides create their WCP nets and it identifies all pareto optimal agreements. An agreement is *pareto optimal* (PO) if there is no other agreement that is better for one negotiator without being worse to its opponent.

First, AutoMed creates two instances of all possible agreements. There is a finite number of issues and values, so the list is finite too. The agreements lists are then sorted using WML ordering in an increasing fashion. The location of an agreement in the list is its *rank*. Next, all non PO agreements are removed from these sets. Finally, the two PO sets are merged into one using the agreements' ranks in the separate PO sorted sets. Agreements which their summed ranks is higher are preferred. The best PO agreement for both sides is the highest on the merged list.

During the negotiation AutoMed searches for an offer to propose. When doing so, the last offer made by each side is identified. AutoMed assumes that the suggested agreement should be a PO agreement relative to both last proposals. In case the given offers are partial agreements, the blanks are filled with the most preferred value as defined the WCP network of the proposing negotiator.

In case the same suggested offer was identified three consecutive times and the missing-value issues were already agreed upon, the agreed value will be used.

AutoMed now searches for a PO agreement to propose. It does that by finding all agreements preferred to the offer made by the opponent in each list. $Combine$ is the joint list.

If $Combine = \phi$ AutoMed has nothing to suggest at this stage. After duplicating $Combine$, a partial version of the first algorithm, is executed in order to produce the list of sorted PO agreements. Again, the agreement AutoMed considers suggesting is the highest ranking in the resulting list. AutoMed should now decide whether to suggest the found offer or not. AutoMed's main objective is the rapid settlement of the dispute therefore, but repeatedly interfering with the negotiation will interrupt it instead of promote it.

To the best of our knowledge there are no guidelines on the subject in the literature. Thus, we developed AutoMed's approach by using trial and error.

AutoMed will intervene if it has reason to believe that its offer will be accepted or open up new thinking directions. It will wait until both sides have proposed an agreement. If in the last round a partial agreement was achieved, it will not interrupt what seems as a productive discussion. If the calculated offer was already presented in the last round it will not be offered again. If the found offer improves both parties' position with respect to their own proposals, AutoMed will choose to present it. The offer will also be presented if AutoMed finds that it improves at least one side's position considerably. On reaching a full agreement, AutoMed checks if it is PO. If not, AutoMed consults the list of sorted PO agreements formerly calculated. Starting at the highest ranking agreement it searches for the first PO agreement which improves both negotiators' outcome and proposes it.

3. EXPERIMENTS

Our experiments were conducted by having two sets of negotiating pairs. One set's negotiation was mediated by AutoMed, while the other set, served as a control group.

3.1 Domain

In our scenario, England and Zimbabwe are members of a convention, negotiating a treaty concerning the trade in tobacco and the tobacco using countries' support of the tobacco growing ones. If no treaty is formed while the convention is at session, it will not be implemented.

Our subjects were divided into pairs, one acting on behalf of each country. Since our subjects were unfamiliar with economic issues and foreign affairs their own preferences were also specified. Five issues were defined, each having 3 or 4 values, one of which represents the status quo. Altogether, there is a total of 432 possible agreements. All the subjects playing the role of the same country were given the same preferences in all experiments. Since the preferences were pre-defined, AutoMed used pre-defined WCP networks[1].

The negotiation last up to 14 time periods of 2 minutes each. If no agreement is reached after 28 minutes, the status quo is enforced. If the time is up and a partial agreement was reached, the missing issues are assigned the status quo values. Each party can also opt out. The defined implications of the status quo and of opting out are defined, along with the influence of the passage of time. England gains money from each time step in which she doesn't support Zimbabwe, which, in turn, looses the support amount.

3.2 Methodology

Two sets of negotiations were conducted. The first consisted of 21 pairs and their negotiations were mediated by AutoMed, the second consisted of 20 pairs which served as a control group. All 82 subjects were students of the Exact Sciences faculty in Bar-Ilan Univ. Instructions and preferences ordering given to both groups were the same.

After a negotiation ended, both participants were required to state their satisfaction level of the outcome by stating a number between 1 representing the lowest possible satisfaction and 10 representing the highest. The participants whose negotiations were mediated were also asked whether they think AutoMed helped find the solution.

3.3 Results

AutoMed aims at concluding the dispute rapidly. All mediated negotiations and 75% of the unmediated ones ended with a full agreement. Two unmediated negotiations ended with opting out, and three exceeded the time limit. The χ^2 test shows that with AutoMed significantly more negotiations were concluded with a full agreement compared to unmediated negotiations ($p < 0.025$).

We used the 2-independent-sample Wilcoxon test to compare the time period of conclusion with and without AutoMed. The negotiations ending with the time limit were calculated as if concluded in time period 15. Negotiations mediated by AutoMed were concluded significantly faster than unmediated negotiations ($p < 0.03$).

7 of the 21 mediated negotiations were concluded with AutoMed's offer. That is, 24 out of 42 participants (57%) reported that AutoMed assisted them. Satisfaction levels were also tested for. Both total and England's satisfaction levels are much higher and Zimbabwe's is slightly higher using AutoMed. Dividing the level of satisfaction into two groups, 1-6 and 7-10, the χ^2 test show that AutoMed produced a significantly higher level where the England role is concerned ($p < 0.01$).

[1]In another experiment we studied the level of satisfaction subjects displayed in expressing their preferences using WCP-net. The results showed that the specification process is concluded within several minutes and the subjects were very satisfied with this expression model

4. RELATED WORK

A number of mediation support systems (MSS) are described in the literature. Family_Winner [1] is an MSS in Australian Family Law. SmartSettle is an MSS that networks multiple parties and manages their confidential information with a neutral Internet site [10]. Unlike them, AutoMed is a fully automated mediator.

The PERSUADER [9] acts as an automated labor mediator relying on Case-Based Reasoning methods, making it difficult to resolve disputes of a nature not yet described in its database. AutoMed relies exclusively on the dispute's definitions and the negotiators' preferences over them.

5. CONCLUSION AND FUTURE WORK

In this paper we present AutoMed, an automatic mediator. Comparing non-mediated negotiations with ones mediated by AutoMed show a significantly shorter negotiation, more agreements reached with a higher satisfactory level.

At the moment AutoMed is presented with a pre-defined set of issues and values. An ability to add and/or change the given values will further enhance the richness of the possible negotiations and help find better suited solutions.

Also, AutoMed does not consider the compromises made by the negotiators in their offers. We plan on sophisticating the middle ground search algorithm to consider the willingness of the negotiator to compromise as well.

Acknowledgement: This research was supported in part by ISF grant #1211/04.

6. REFERENCES

[1] E. Bellucci and J. Zeleznikow. Family_winner: A computerised negotiation support system which advises upon australian family law. In *ISDSS01*, 2001.

[2] V. Bonnet, K. Boudaoud, M. Gagnebin, J. Harms, and T. Shultz. Online dispute resolution systems as web services. In *9th Workshop of the HP-OVUA*, 2002.

[3] C. Boutilier, R. Brafman, C. Geib, and D. Poole. A constraint-based approach to preference elicitation and decision making. In *AAAI Spring Symposium*, pages 19–28, 1997.

[4] R. Fisher and W. Ury. *Getting to Yes:Negotiating Agreement Without Giving In*. Houghtonn Mifflinn, NY, 1981.

[5] P. Hoz-Weiss, S. Kraus, J. Wilkenfeld, and T. E. Santmire. An automated negotiator for an international crisis. In *AAAI-2002, Intelligent Systems Demos*, 2002.

[6] S. Kraus. *Strategic Negotiation in Multi-Agent Environments*. MIT Press, Cambridge, USA, September 2001.

[7] R. Lin, S. Kraus, J. Wilkenfeld, and J. Barry. An automated agent for bilateral negotiation with bounded rational agents with incomplete information. In *ECAI*, 2006.

[8] F. Rossi, K. Venable, and T. Walsh. CP networks: semantics, complexity, approximations and extensions. In *CP-2002*, Cornell, 2002.

[9] K. Sycara. Problem restructuring in negotiation. *Management Science*, 37(10), October 1991.

[10] E. Thiessen and J. M. Jr. Beyond win-win in cyberspace, http://www.smartsettle.com/. *ADR in Cyberspace Symposium*, 1999.