Mixing Behaviour-dependent and -independent Tactics in Multi-issue Negotiation

(Extended Abstract)

Jan Richter
Swinburne University of Technology
Hawthorn,3122, Victoria, Australia
jrichter@groupwise.swin.edu.au

Ryszard Kowalczyk
Swinburne University of Technology
Hawthorn,3122, Victoria, Australia
rkowalczyk@groupwise.swin.edu.au

ABSTRACT

We present mechanisms for the creation of strategies by mixing behaviour-dependent and -independent tactics in multi-issue negotiation. The traditional linear weighted combination of tactics may generate non-monotonic utilities over time even in the case of a monotonic series of opponent's offers. The proposed methods guarantee monotonic utilities, which can improve negotiation outcomes in many scenarios.

Categories and Subject Descriptors

I.2.11 [**Artificial Intelligence**]: Distributed Artificial Intelligence

Keywords

Negotiation, Strategies, Tactics, Mixing, Utility

1. INTRODUCTION

In modern autonomous systems, negotiation between software agents is key to facilitate decision-making among two or more parties which are in conflict about their goals. Agents can use numerous tactics and combinations of them to create strategies for negotiation. Using the traditional method, the linear weighted combination of tactics, a non-monotonic series of offers can be the result in scenarios where behaviour-independent and imitative tactics are mixed even though opponent's concession curves are monotonic and weights are static. In multi-issue negotiation this may cause a non-mono-tonic series of utilities which can lead to less optimal outcomes or delayed agreements. If partners also apply imitative tactics to some degree this behaviour is propagated to next rounds. Based on the traditional mixing method we derive further mixing methods to ensure monotonic utilities even in cases where weights change dynamically.

2. NEGOTIATION TACTICS

We use concepts of the service-oriented negotiation model [2, 1] where two parties negotiate on a number of real-valued issues such as price or delivery time. The sequence of all offers exchanged until time n specifies the negotiation thread $X^{t_n}_{a\leftrightarrow b} = (x^{t_1}_{a\rightarrow b}, x^{t_2}_{b\rightarrow a}, x^{t_3}_{a\rightarrow b}, \dots)$ with $t_1, t_2, \dots \leq t_n$. Each party has a utility function $V^a : [min^a_j, max^a_j] \rightarrow [0,1]$ associated to each issue assigning utilities to offers within their acceptable intervals. The additive utility function $V^a(x) = \sum_j V^a_j(x_j)$ where w^a_j represents the relative importance of issue j with $\sum_{1\leq j\leq p} w^a_j = 1$. For simplicity and applicability of the model we assume monotonic utility functions. Offers are exchanged alternatively during the negotiation until one agent accepts or withdraw, or the deadline is reached. Using this responsive mechanism three different families of tactics such as time-, resource- and behaviour-dependent can be used. Even though the number of possible tactics is infinite the mixing mechanisms are not limited to tactics presented in [1]. We therefore specify two general classes of monotonic behaviour-independent and dependent tactics:

Definition 1. Given a negotiation between agents a and b at time t_n, $\tau(t_{n+1})$ is a pure monotonic behaviour-independent tactic which generates the next counteroffer under the condition that $\tau(t_{n+1}) \geq \tau(t_{n-1})$ if V^a decreasing or $\tau(t_{n+1}) \leq \tau(t_{n-1})$ if V^a increasing.

Definition 2. Given a negotiation thread $X^{t_n}_{a\leftrightarrow b}$ between agents a and b at time t_n, $\tau(\tilde{X}^{t_n}_{a\leftrightarrow b})$ is a pure monotonic behaviour-dependent tactic with $\tilde{X}^{t_n}_{a\leftrightarrow b}$ being a subset of $X^{t_n}_{a\leftrightarrow b}$, which contains all offers used by the tactic to generate the next counteroffer under the following condition: For any $x^{t_r}_{b\rightarrow a}, x^{t_s}_{b\rightarrow a} \in \tilde{X}^{t_n}_{a\leftrightarrow b}$ with $r \geq s$ and $s, r \in 1..n$ it follows that (i) if V^a decreasing and $x^{t_r}_{b\rightarrow a} \leq x^{t_s}_{b\rightarrow a}$ then $\tau(\tilde{X}^{t_n}_{a\leftrightarrow b}) \geq \tau(\tilde{X}^{t_{n-2}}_{a\leftrightarrow b})$ or (ii) if V^a increasing and $x^{t_r}_{b\rightarrow a} \geq x^{t_s}_{b\rightarrow a}$ then $\tau(\tilde{X}^{t_n}_{a\leftrightarrow b}) \leq \tau(\tilde{X}^{t_{n-2}}_{a\leftrightarrow b})$.

Definition 2 includes all functions that use some of the opponent's historical offers to propose next counteroffers. The proposed series of offers is monotonic if opponent's offers are monotonic as well. Once non-monotonicity is introduced by one partner it is propagated by the other partner depending on the degree of applied imitative behaviour.

3. STRATEGIES

Strategies determine the best course of actions to maximize utilities of outcomes while reaching agreements. Based on a weight matrix with $\gamma_{ji} \in [0,1]$ representing the weight for tactic i and issue j different combinations of tactics can be used to generate counteroffers and obtain different behaviours. With $\sum_{i=1}^{m} \gamma_{ji} = 1$ each row of the matrix corresponds to a weighted linear combination of m tactics for one issue. The weighted counterproposal extends the current negotiation thread by appending $x^{t_{n+1}}_{a\rightarrow b}$.

Cite as: Mixing Behaviour-dependent and -independent Tactics in Multi-issue Negotiation, (Extended Abstract), Jan Richter, Ryszard Kowalczyk, *Proc. of 8th Int. Conf. on Autonomous Agents and Multiagent Systems (AAMAS 2009),* Decker, Sichman, Sierra and Castelfranchi (eds.), May, 10–15, 2009, Budapest, Hungary, pp. 1219–1220
Copyright © 2009, International Foundation for Autonomous Agents and Multiagent Systems (www.ifaamas.org), All rights reserved.

Linear weighted combination of tactics. According to the weight matrix tactics can be mixed [1] as $x_{a\to b}^{t_{n+1}}[j] = \sum_{i=1}^{m} \gamma_{ji} \cdot \tau_{ji}$. No distinction is made between tactics from definition 1 and 2, hence τ_{ji} represents any tactic used to negotiate issue j. This method can create non-monotonic concession curves in scenarios where behaviour-independent and imitative tactics are used even though the series of opponent's offers is monotonic (see Example 4). Since negotiation parties should make concessions or seek for joint improvements (trade-off) in a negotiation [3] [1], the risk of partners' withdrawal is increased if agents make proposals with higher utilities for themselves. As utility functions are private information, in multi-issue negotiations parties could assume a trade-off is being proposed and therefore still hold to withdraw. However, in such cases possible agreements are delayed. By applying simple constraints $C(x_{a\to b}^{t_{n+1}}, x_{a\to b}^{t_{n-1}})$ with $C \equiv Min$ if V^a is decreasing and $C \equiv Max$ if V^a is increasing, non-monotonic utilities can be avoided. In such cases agent's concessions become zero.

Individual negotiation thread-based mixing. In order to calculate imitative tactics using above method the agent's last offers in the negotiation thread are used. The imitative part of the mixed strategy does therefore not represent a true pure behaviour-dependent tactic, because all agent's previous offers result from the mixed strategy instead of the single imitative tactic(s). The imitative components hence depend not only on opponent's offers but also directly on the behaviour-independent tactics in the mixed strategy. To resolve this last offers have to be kept from individual imitative negotiation threads $X_{a\leftrightarrow b}^{t_n}[j,k]$ where k denotes the k'th behaviour-dependent tactic $\tau_{jk}(\tilde{X}_{a\leftrightarrow b}^{t_n}[j,k])$ for issue j:

$$x_{a\to b}^{t_{n+1}}[j] = \sum_{i=1}^{l} \gamma_{ji} \cdot \tau_{ji}(t_{n+1}) + \sum_{k=l+1}^{m} \gamma_{jk} \cdot \tau_{jk}(\tilde{X}_{a\leftrightarrow b}^{t_n}[j,k])$$

with $m-l$ and l denoting the number of behaviour-dependent and -independent tactics respectively. This method generates monotonic utilities over time in cases of monotonic opponent's offers. If partners introduce non-monotonicity simple constraints can be applied to $\tau_{jk}(\tilde{X}_{a\leftrightarrow b}^{t_n}[j,k])$ with $C(\tau_{jk}(\tilde{X}_{a\leftrightarrow b}^{t_n}[j,k]), x_{a\to b}^{t_{n-1}}[j,k])$ where $C \equiv Min$ if V^a is decreasing and $C \equiv Max$ if V^a is increasing.

Concession-based mixing. This method uses the sum of individually calculated next concessions for each tactic:

$$x_{a\to b}^{t_{n+1}}[j] = x_{a\to b}^{t_{n-1}}[j] + \\ + \sum_{i=1}^{l} \gamma_{ji} \cdot (\tau_{ji}(t_{n+1}) - \tau_{ji}(t_{n-1})) + \\ + \sum_{k=l+1}^{m} \gamma_{jk} \cdot (\tau_{jk}(\tilde{X}_{a\leftrightarrow b}^{t_n}[j]) - x_{a\to b}^{t_{n-1}}[j])$$

with $m-l$ and l denoting the number of behaviour-dependent and -independent tactics respectively. Concessions are calculated as differences between two succeeding offers for all behaviour-independent tactics. Since we cannot generate concessions for imitative tactics without additional negotiation threads the next imitative offers at time t_{n+1} and agent's last offer $x_{a\to b}^{t_{n-1}}$ are used instead. Similar to the thread-based method this approach ensures a monotonic series of offers but now also for dynamically changing weights. A simple constraint guarantees monotonic utilities in cases of non-monotonic series of offers from the opponent with $C(\tau_{jk}(\tilde{X}_{a\leftrightarrow b}^{t_n}[j]) - x_{a\to b}^{t_{n-1}}[j], 0)$ applied to the imitative concession where C is Min or Max for V^a de- or increasing.

4. EXAMPLE

Figure 1 shows concession curves and additive utilities for a bilateral, two-issue negotiation. Both parties use a mixed strategy for issue price with static weights and pure tactics for issue volume. We use tactics from [1] as follows:

Price ($w_{price}^a = 0.7$)	Price ($w_{price}^b = 0.5$)
$min_{price}^a = 30$, $max_{price}^a = 50$ Mixed Strategy ($\gamma_{price} = 0.2$) $\tau_{price,time}$: exponent. $\beta = 0.7$ $\tau_{price,beh}$: absolute tft, $\delta = 1$	$min_{price}^b = 40$, $max_{price}^b = 60$ Mixed Strategy ($\gamma_{price} = 0.6$) $\tau_{price,time}$: polynomial $\beta = 4$ $\tau_{price,beh}$: relative tft, $\delta = 1$
Volume ($w_{vol}^a = 0.3$)	Volume ($w_{vol}^b = 0.5$)
$min_{vol}^a = 20$, $max_{vol}^a = 30$ $\tau_{vol,time}$: polynomial, $\beta = 1$	$min_{vol}^b = 15$, $max_{vol}^b = 25$ $\tau_{vol,beh}$: absolute tft, $\delta = 1$

The linear weighted combination of tactics produces non-monotonic concession curves which at the same time result in a non-monotonic series of utilities (upper curve: agent a's utilities from own offers; lower curve: a's utilities from offers proposed by agent b). Using the thread-based mixing mechanism agreement can be achieved much earlier with slightly higher utilities for agent b. Curves for the concession-based and thread-based method are similar in this example.

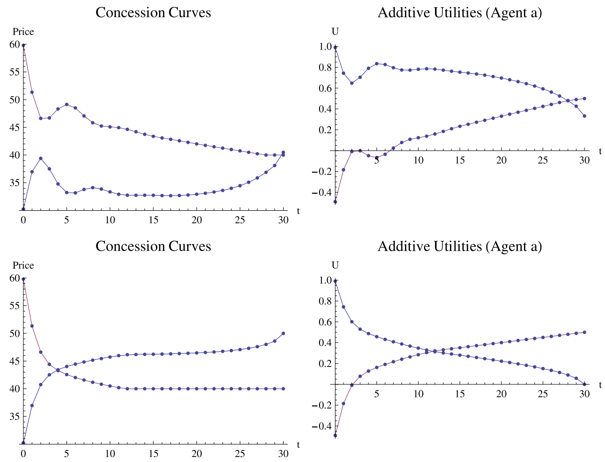

Figure 1: Linear weighted combination of tactics (upper) vs. thread-based mixing (lower)

5. CONCLUSION

In this paper we have presented different mechanisms to mix pure tactics in multi-issue negotiation strategies. It has been demonstrated that the traditional linear weighted combination of tactics can expose non-monotonic utilities over time for static mixed strategies in the case where behaviour-dependent and -independent tactics are used even when opponent's concession curves are monotonic. In such cases these perturbations are difficult to predict and can lead to less optimal outcomes or delayed agreements. The proposed methods solve this problem by guaranteeing monotonic utilities over time for static as well as dynamic mixed strategies.

6. REFERENCES

[1] P. Faratin. *Automated Service Negotiation Between Autonomous Computational Agents.* PhD thesis, University of London, 2000.

[2] P. Faratin, C. Sierra, and N. R. Jennings. Negotiation decision functions for autonomous agents. *Robotics and Autonomous Systems*, 24(3–4):159–182, 1998.

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