On Monotonic Mixed Tactics and Strategies for Multi-Issue Negotiation

(Extended Abstract)

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ABSTRACT

We present an initial comparative evaluation between monotonic mixing and the traditional linear weighted combination of tactics in a multi-issue negotiation scenario. As the traditional mixing method may produce a non-monotonic sequence of utilities of proposed offers in case imitative and non-imitative tactics are mixed together (even when weights are static) we demonstrate that both agents can gain higher utilities in many scenarios when using monotonic mixing.

Categories and Subject Descriptors

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

General Terms

Algorithms

Keywords

Agent, Negotiation, Tactics, Mixed Strategies, Utility

1. INTRODUCTION

Agent-based negotiation can be considered as collective decision making between rational software agents that are in conflict about their goals thereby involving cooperative and competitive elements. In such environments, the agents have incomplete information about the opponent's behaviour and their utility structures, and typically use a negotiation tactic or a mix of tactics to specify their negotiation strategy. A simple but widely used technique for mixed strategies is the linear weighted combination of tactics [1]. In many scenarios, however, when behaviour-dependent tactics (imitating the opponent's behaviour to some degree) and behaviour-independent tactics (e.g. tactics only depending on time) are mixed using this method, non-monotonicity in the offer curves may emerge coincidentally, even if mixing weights and strategy settings are *static*. In single-issue negotiation, such behaviour can be considered irrational by the other agent since the opponent proposes offers which increase its own utility, and hence also increase the risk of a withdrawal of the agent. In multi-issue negotiations, it is difficult to detect if the opponent proposes offers with higher utilities for herself compared to its previous offers due to the unknown utility functions or possible trade-off proposals (where the offer sequence for an issue may be non-monotonic). It is often argued [2, 1] that the negotiation process should be designed in a way that agents make concessions, or seek for joint improvements (trade-offs) in a negotiation. This implies monotonic behaviour: an agent makes proposals such that its sequence of aggregated utilities of its own offers is either monotonically decreasing (concession) or remains the same (trade-off). However, the non-monotonicity in the offer curves and the sequence of aggregated utilities may emerge at any time without the agent's intervention if imitative and non-imitative tactics are mixed together by a linear weighted combination. As a result, the final agreement is delayed, or, if negotiation intervals overlap only partially and deadlines differ, no agreement may be reached. In addition, the negotiation outcomes can vary significantly with lower utilities for both parties as compared to mixed strategies proposing offers along a monotonic decreasing utility. Due to the dynamic and imitative nature of the underlying interacting decision functions, the strategy parameters expose a *high sensitivity* in the sense that small changes in the initial settings of an agent may lead to larger changes in the outcome. Due to these reasons we propose two monotonic mixing mechanisms which avoid such undesirable effects and provide initial experimental results for some multi-issue negotiation scenarios.

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2. MONOTONIC MIXING MECHANISMS

The two mixing mechanisms proposed are linear weighted combinations of tactics which distinguish between behaviour-dependent and -independent tactics in the mix. The first, *negotiation thread-based* mixing, uses for each imitative tactic an individual negotiation thread to generate next offers:

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

where $x_{a\to b}^{t_{n+1}}[j]$ is the next offer of agent a for issue j and $\tilde{X}_{a\leftrightarrow b}^{t_n}[j,k]$ is the sequence of offers used from the individual negotiation thread $X_{a\leftrightarrow b}^{t_n}[j,k]$ for the k'th imitative tactic τ_{jk}. The rationale behind is that the individual threads for each imitative tactic ensure that the offers used do not interfere with other tactics in the mix. However, as these threads do not represent actual negotiations, another method, the *concession-based* mixing, calculates the linear weighted combination of individual *next concessions* for each tactic:

$$x_{a\to b}^{t_{n+1}}[j] = x_{a\to b}^{t_{n-1}}[j] + \sum_{i=1}^{l} \gamma_{ji} \cdot (\tau_{ji}(t_{n+1}) - \tau_{ji}(t_{n-1})) + \\ + \sum_{k=l+1}^{m} \gamma_{jk} \cdot (\tau_{jk}(\tilde{X}_{a\leftrightarrow b}^{t_n}[j]) - x_{a\to b}^{t_{n-1}}[j]). \quad (2)$$

where τ_{ji} represents a behaviour-independent tactic and τ_{jk} an imitative tactic in the mix, respectively. Both of the above methods avoid the dynamic emergence non-monotonic sequence of offers (and hence also of the sequence of aggregated utilities). However, due to the involved imitative tactics, if the opponent *introduces* non-monotonic behaviour into its course of offers it may still be copied to some degree. The advantage herein is that if the opponent tries to increase its own overall utility, the agent is not forced to propose a monotonic offer sequence. This, however, may as well result in the non-desirable effects described previously.

3. INITIAL EXPERIMENTAL RESULTS

As the number of possible mixes of tactics is infinite, the evaluation is restricted to a mix of two tactics, one behaviour-dependent and one time-dependent [1], with static weights throughout the encounter and the following settings:

- *Time-dependent (polynomial)*:
  Conceder: $\beta \in \{3, 7\}$; Boulware: $\beta \in \{0.1, 0.3\}$
- *Behaviour-dependent*:
  absolute tft: $\delta = 1, R(M) = 0$; relative tft: $\delta = 1$
- *Weights*: Small: $\gamma \in \{0.1, 0.3\}$; Large: $\gamma \in \{0.7, 0.9\}$

We use initial letters of tactics to indicate the respective group of mixed strategies (e.g. "CaS": conceder mixed with absolute tft by small weights). Before considering a multi-issue scenario we are interested in when non-monotonicity emerges in static strategies using the above settings. Assume two agents, a buyer (b) and a seller (s), negotiate about a certain issue where intervals are partially overlapping with $min^s = 15$, $max^s = 30$, and $min^b = 10$, $max^b = 25$, and deadlines are equal with $t^s_{max} = t^b_{max} = 20$. Table 1 illustrates the rate (%) of negotiations where non-monotonic offer curves occurred in the case of both agents applying the traditional linear weighted combination for the particular strategy group. Numbers below the rate are the maximum variation in terms of non-monotonicity measured as utility for the seller (left) and buyer (right). As we can see the dynamically emerging non-monotonicity in static settings is not a negligible effect in negotiation. Moving to the multi-issue case, using the first issue from above we add a second issue also having partial overlap of intervals with $min^s_2 = 30$, $max^s_2 = 50$, and $min^b_2 = 20$ and $max^b_2 = 40$, and, in order to provide a more realistic scenario, the agents may also have different deadlines with $t^s_{max} \in \{10, 20, 30\}$ and $t^b_{max} = 20$. The performance is measured using the linear weighted additive utility mapping offers into the interval [0.1,1] to ensure that successful negotiations at the reservation point are scored higher than failed ones. Figure 1 shows the results for two scenarios, where the buyer applies more cooperative (CaS/CaL) or more competitive strategies (BaS/Bal) and the seller plays different combinations (left: buyer, right: seller utility, both using the traditional (light) or concession-based (dark) mixing). We can see that in the first scenario utility is shifted from the seller (with non-monotonic behaviour) to the buyer whereas in the second scenario both agents significantly gain higher utilities when using the monotonic mixing mechanism.

s / b	CaS	CaL	BaS	BaL
CaS	0% 0/0	12% 0.03/0	37% 0.28/0.36	100 % 0.17/0.2
CaL	0% 0/0	12% 0.01/0	75% 0.06/0.4	100% 0.03/0.19
BaS	87% 0.36/0.18	75% 0.36/0.02	0% 0/0	0 % 0/0
BaL	69% 0.06/0	100% 0.17/0	0 % 0/0	0% 0/0
CrS	0% 0/0	0% 0/0	12 % 0.54/0.42	100 % 0.29/0.2
CrL	19% 0.03/0.03	25% 0.01/0	75% 0.08/0.41	100% 0.06/0.19
BrS	37% 0.5/0.32	37% 0.41/0.02	50% 0.64/0.48	0% 0/0
BrL	94% 0.14/0	100% 0.27/0	0% 0/0	0% 0/0

Table 1: Non-monotonicity in negotiations

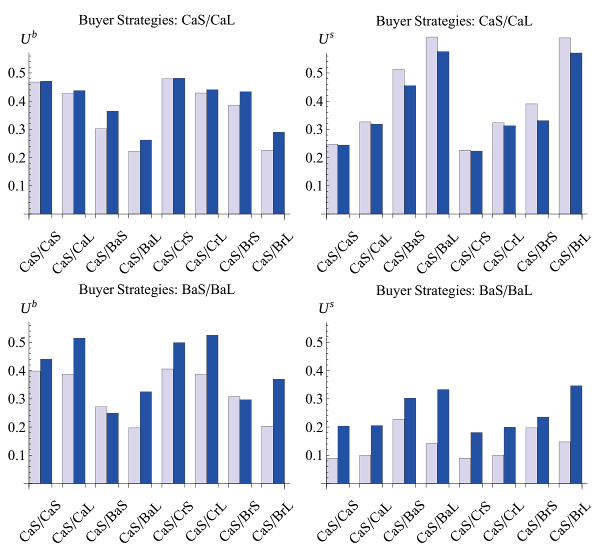

Figure 1: Traditional vs. concession-based mixing

4. CONCLUSION

We have presented initial experimental results for the comparison between the monotonic concession-based mixing and the traditional linear weighted combination of tactics in multi-issue negotiation. The results show that the proposed method may provide utility gains for both agents in many scenarios thereby avoiding the dynamically emerging non-monotonic utility sequence of proposed offers in mixed strategies.

5. REFERENCES

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