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Adaptive conceding strategies for automated trading agents in dynamic, open markets

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ABSTRACT

One of the crucial issues of automated negotiation in multi-agent systems is how to reach an agreement when a negotiation environment becomes open and dynamic. Even though some strategies have been proposed by researchers, most of them can only work within a static negotiation environment. In this paper, we present a model for designing a strategy for agents that makes adjustable rates of concession by negotiating according to the changes of environments with uncertain and dynamic outside options. This proposal is based on the market-driven agents (MDAs) model, and is guided by four factors in order to determine the degree of concession. These factors are *trading opportunity*, *trading competition*, *trading time and strategy*, and *eagerness*. The contribution of this paper is extending the MDAs model to an open and dynamic negotiation environment by considering both the current and potential changes of the environment.

1. Introduction

Automated negotiation [20] has been an active research area in recent years. Research on negotiation agents [13,16] has received a great deal of attention in the areas of multi-agent systems and e-commerce [11,8]. Currently, one of the most crucial issues for automated negotiation is how to reach an agreement when the negotiation environment becomes open and dynamic. Although some agent-based systems [19,3,2,10,9,26,17] have been proposed and implemented successfully by researchers, agents involved in these systems usually can only adopt predetermined strategies to negotiate with others. Therefore, when the negotiation environment is open and dynamic, such as more products and services becoming available and negotiators either entering or leaving the negotiation dynamically, agents cannot provide reasonable responses to changes in the negotiation environment by adopting their current negotiation strategies straightway. Furthermore, negotiators may also be bounded by restrictions such as deadlines and resource limitations. Agents may need to modify their negotiation strategies too when the pressure from these restrictions changes. The Market-Driven Agents (MDAs) model [22,24,23,18] is one strategy which takes into account the relationship between agents' negotiation strategies and the negotiation environment. Through comparing the MDAs model [23,22,25] and other negotiation strategies [19,3,2,10,9,26], the efficient performance of the MDAs model has been illustrated. In the MDAs model, agents are guided by four concession factors, and these factors determine how much concession agents can give during the negotiation based on the environment. These concession factors are *trading opportunity* (see Section 2.2), *trading competition* (see Section 2.3), *trading time and strategy* (see Section 2.4) and *eagerness* (see Section 2.5).

However, even though the MDAs model considers the relationship between agents' strategies and the negotiation environment, it does not take into account the situation when the negotiation environment becomes open and dynamic. In an open and dynamic environment, agents may enter into and leave off the negotiation freely, and so the uncertainty of the negotiation may be increased too. In order to have a broad view on the negotiation environment, we adopt Sycara's model [14,15] to classify negotiations according to the complexity of their environment. The model is illustrated in Fig. 1, and according to this model, negotiations are divided into three levels. The negotiation which is processed within the simplest environment is named *single-threaded negotiation*. In this level, the negotiation is carried out between only two agents without any outside options. None of the negotiators can leave off the negotiation before an agreement is reached or a deadline is met, and also no agent can enter into the negotiation during the process. The second level is named *synchronized multi-threaded negotiations*, in which the negotiation is processed among multiple agents. Therefore, agents need more complex negotiation strategies in order to reach an agreement when they face more than one negotiators. As with the first level, all negotiators are

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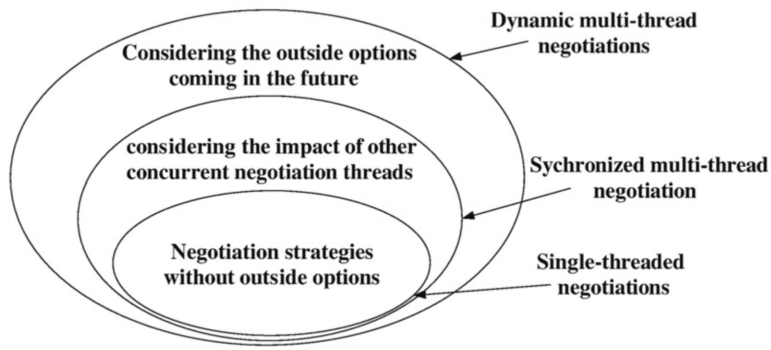

Fig. 1. A nested view of general negotiation models [14].

still not allowed to leave off and enter into the negotiation freely. Therefore, in this level, agents make any decision in the negotiation based on the current negotiation environment only. The third level is named *dynamic multi-threaded negotiations*. In this level, all negotiators can leave and enter the negotiation dynamically. Therefore, agents should think about not only the current situation but also possible changes to the negotiation environment. According to the classification, in the current stage, the MDAs model can work well on the first two levels, but cannot handle negotiation on the third level. In order to address this issue, in this paper, we propose to extend the MDAs model to third level negotiation by considering the uncertain and dynamic outside options.

The rest of this paper is organized as follows. In Section 2, the principle of the MDAs model is introduced briefly. Section 3 introduces the proposed mechanisms to extend the MDAs model. Section 4 illustrates the experimental results. Section 5 discusses related works. Section 6 concludes this paper and outlines our future work.

2. A model for market-driven agents

In this section, the principle of the MDAs model [24] is recalled briefly and in particular all four concession factors in MDA are also recapped. Finally, we discuss the limitations of the MDAs model in order to highlight the motivation of this paper.

2.1. Principle of MDAs model

In order to make reasonable negotiation strategies according to the negotiation environment, agents may need to modify the spread k that is defined as the difference between an agent's proposal and the counterproposal of its trading partner. For example, if the price of a car is $10,000, and the buyer would only like to pay $9000, then the spread k for both seller and buyer is $1000. In general, when k is large, the probability that agents may complete the negotiation will be decreased, and conversely when k is small, the probability will be increased. Therefore, by modifying the spread k, agents can maintain the benefits gained from their partners and increase the likelihood of completing the negotiation. Let k' denote the spread in the next negotiation round, then k' is determined by assessing current negotiation situation as follows:

$$k' = O(n, \omega_i, \upsilon)C(m, n)T(t, t', \tau, \lambda)E(\varepsilon)k \tag{1}$$

where $O(n, w_i, v)$ is the factor for *trading opportunity* that determines the amount of concession according to agents' expectations about the negotiation, the number of partners and their partners' offers (see Section 2.2); and $C(m, n)$ is the factor for *trading competition*, which is determined by the probability that an agent is ranked as the most preferred trader by at least one of its partners (see Section 2.3); $T(t, t', \tau, \lambda)$ is the factor for *trading time and strategy* that determines agents' rates on concession by considering time constraints (see Section 2.4); $E(\varepsilon)$ is the factor for *eagerness* that determines the amount of concession by considering agents' eagerness to finish the negotiation (see Section 2.5). The Formula (1) assumes that all concession factors are independent (see our previous papers [22,24,23,18] for detailed explanation of this formula). In the following subsections, each of these concession factors will be discussed in detail, respectively.

2.2. Trading opportunity

In MDAs, the following factors are considered in order to determine the trading opportunity:

- the number of partners n;
- the spread k between an agent and its partners; and
- the probability p of completing the negotiation.

Let p and p' present the probabilities of an agent completing the negotiation in the current and next negotiation round, respectively. Let k and k' be values of the current and next spreads, respectively. If the distance between p and p' is large, in order to keep a reasonable probability of finishing the negotiation, agents may increase the distance between k and k'. By contrast, if the distance between p and p' is small, agents may decrease the distance between k and k' in order to maintain their benefits. The relationship between these four factors is represented as follows:

$$k' = \frac{p}{p'} \times k \tag{2}$$

Suppose in a negotiation round, agent B_1's last offer is represented as a utility vector $\upsilon = (\upsilon_b, \upsilon_s)$ and its partner S_1's offer is a utility vector $\omega = (\omega_b, \omega_s)$. B_1's last offer generates a payoff of υ_b for itself and υ_s for S_1; and S_1's offer generates a payoff of ω_s for itself and ω_b for B_1. Let c_b denote the worst possible utility (*conflict utility*) for B_1. If the subjective probability of B_1 obtaining c_b is p_c, we have:

$$[(1-p_c)\upsilon_b + p_c c_b] \leq \omega_b \tag{3}$$

According to Eq. (3), the highest conflict probability that B_1 may encounter is the maximum value of p_c as follows:

$$p_c = \frac{\upsilon_b - \omega_b}{\upsilon_b - c_b} = \frac{k}{\upsilon_b - c_b} \tag{4}$$

Consequently, the aggregated conflict probability that B_1 may encounter by considering all partners is:

$$P_c = \prod_{i=1}^{n} p_i = \prod_{i=1}^{n} \frac{k_i}{\upsilon_b - c_b} = \frac{\prod_{i=1}^{n}(\upsilon_b - \omega_i)}{(\upsilon_b - c_b)^n} \tag{5}$$