Conceding Strategy on Multi-agent Argumentation-based Negotiation in E-commerce

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Abstract

Argumentation-based approach to negotiation, which allows agents to exchange additional information or argue their beliefs and other mental attitudes during the negotiation, is gaining increasing popularity for its potential ability to overcome the limitations of conventional approaches. In this paper, a mechanism of how argument gives effect on the negotiation conceding strategy is analyzed. Furthermore, a time-constraint-based conceding strategy is proposed, considering the impact of argument. At last, experiment is designed to illustrate and verify the proposed strategy, and the result demonstrates that argument have the ability to improve the effectiveness of negotiation.

Keywords: multi-agent negotiation, argumentation-based negotiation, conceding strategy, negotiation strategy

1. Introduction

Concession strategy has been an active research issue in the multi-agent negotiation areas. In Liang and Dong's electronic market prototype system[1], three bargaining strategies are applied: ① giving a great discount at the initial bid, and gradually reducing the concession, the buyer will feel the effect is gradually reduced. ②giving a smaller discount in the initial bid, then gradually increasing the concession, the buyer will feel the effect is gradually increased. ③always use the same discount price. In the Market-Driven Agents model(MDAs) proposed by Sim[2], agents are guided by four concession factors to determine how much concession agents can give during the negotiation based on the environment. These four factors are opportunity, competition, time strategy, and eagerness. Fenghui Ren et al. improve Sim's MDAs model and propose an adaptive strategy[3], considering that negotiating agents can leave and enter negotiation freely during negotiation. In the multi-attribute negotiation framework[4] by Lai and Sycara, a preference-based concession utility function is built to restrict the possible concession space, which is subject to change in light of new information during negotiation.

In the field of argumentation-based negotiation, how argument influences the agent's decision mechanism is an important issue. Jennings et al. believe that argumentation allows agents to express additional information, include information to declare one's negotiation position and to affect the other's negotiation position [5]. Rahwan regards that, if a proposal is accompanied with an

effective argument, the possibility of being accepted by the counterpart will be greatly increased [6].

In the literatures, although there are many researches about conceding strategy in the area of multi-agent negotiation, the argument's impact is seldom referred to. And in the field of argumentation-based negotiation, argument's influence on strategy is studied mostly on theoretical and formal level; there are seldom researches about how argument gives impact on the conceding spread or conceding degree in a particular negotiation situation.

In this paper, the main issue is to study the mechanism of how the argument influences the conceding strategy in the E-commerce negotiation. A model of argument's influence on conceding strategy is proposed, and a revision function is pointed out, as well as an algorithm example. At last, an experiment is carried out to verify and illustrate the model and strategy.

2. A model of argumentation effect on negotiation strategy

In argumentation-based negotiation, argument is regarded to have a great impact on the negotiation process. If the opponent's offer is combined with a strong argument, it will have a great effect on the concession spread. If the argument is stronger, the counterpart will probably make larger concession degree. The calculation of argument strength has been studied in some researches [7].

$$
M_A^j(t) = \begin{cases} [r_A^j - P_{A \to B}^j(t)] \times Strength(A_{B \to A}^j(t)) \times \varepsilon \\ \qquad (when \qquad O_{B \to A}^j(t) \geq r_A^j) \\ [O_{B \to A}^j(t) - P_{A \to B}^j(t)] \times Strength(A_{B \to A}^j(t)) \times \varepsilon \\ \qquad (when \qquad P_{A \to B}^j(t) < O_{A \to A}^j(t) < r_A^j) \\ O_{B \to A}^j(t) - P_{A \to B}^j(t) \\ \qquad (when \qquad O_{B \to A}^j(t) \leq P_{A \to B}^j(t)) \end{cases}
$$

$$(1)$$

2.1. Model background and description

1) Agent A negotiates with agent B negotiate about some specific product, and argumentation-based mechanism is used during negotiation. As for the framework, protocol and process of the negotiation, article [8] can be referred to.
2) Agent A has some negotiation items, such as price, delivery etc. r_A^j means the reservation value of negotiation item j of agent A. And e_A^j is the expectation value of negotiation item j of agent A. If item j is cost-based type attribute for agent A, $e_A^j < r_A^j$; If item j is benefit-based type attribute, $e_A^j > r_A^j$.
3) For negotiation item j, at time t, agent has its expected proposal value $P_{A \to B}^j(t)$, which is calculated by time-constrained strategy. At the same time, agent A receives the proposal value $O_{B \to A}^j(t)$ coming from agent B, with an argumentation $A_{B \to A}^j(t)$ to support its proposal. Agent A will evaluate the argument and has its strength value stored as $Strength(A_{B \to A}^j(t))$, $0 \leq Strength(A_{B \to A}^j(t)) \leq 1$. Greater the value is, more impact it will have on agent A's concession degree.

2.2. Model definition

At time t, about negotiation item j, agent A has its pre-determined expected proposal value to agent B, expressed as $P_{A \to B}^j(t)$. An argument $A_{B \to A}^j(t)$, at the same time about the same item from the counterpart, agent B, may has a certain effect on the proposal value $P_{A \to B}^j(t)$, and the effect can be expressed as a revision function $M_A^j(t)$.

Here, the attribute type of item j should be taken into consideration. If it is cost-based type attribute, $M_A^j(t)$ is described

as formula (1), and benefit-based type attribute as formula (2).

In formula (1) and (2), ε ($\varepsilon \in [0,1]$) is an environment revision parameter. When the competition pressure is bigger, or negotiators were more eager to reach an agreement, ε is larger.

3. Conceding strategy based on time-constraint and argument-effect (CSBOTCAAE)

3.1. Time-constraint conceding strategy

In the existing negotiation system, time-constraint strategy is often used to determine conceding degree. In this paper, negotiation agent A will employ the following strategy to calculate the expectation proposed value of item j at time t, expressed by $P_{A \to B}^{j}(t)$.

$$M_A^j(t) = \begin{cases} [P_{A \to B}^j(t) - r_A^j] \times Strength(A_{B \to A}^j(t)) \times \varepsilon \\ \quad (when \quad O_{B \to A}^j(t) \le r_A^j) \\ [P_{A \to B}^j(t) - O_{B \to A}^j(t)] \times Strength(A_{B \to A}^j(t)) \times \varepsilon \\ \quad (when \quad r_A^j < O_{B \to A}^j(t) < P_{A \to B}^j(t)) \\ P_{A \to B}^j(t) - O_{B \to A}^j(t) \\ \quad (when \quad P_{A \to B}^j(t) \le O_{B \to A}^j(t)) \end{cases}$$

(2)

The strategy is shown in formula (3).

$$P_{A \to B}^j(t) = P_{A \to B}^j(t-1) + (r_A^j - e_A^j) \frac{t^{\lambda_A^j} - (t-1)^{\lambda_A^j}}{\tau_A^{\lambda_A^j}}$$

(3)

$$(t >= 1, \lambda_A^j >= 0, \tau_A >= t)$$

We give the following instructions of formulas (3).

1) $P_{A \to B}^j(t-1)$ is the proposed value of agent A to B at time ($t-1$) about negotiation item j. $P_{A \to B}^j(0)$ means A's first proposal value of item j.

2) $(t^{\lambda_A^j} - (t-1)^{\lambda_A^j-1}) * (r_A^j - e_A^j)/\tau_A^{\lambda_A^j}$ reflects the adjusted value of negotiation item j's

proposed value between two contiguous time interval.

3) If $r_A^j > e_A^j$, item j is cost-based type attribute, such as purchase price of buyer agents. The smaller, the better. Usually, negotiators will gradually increase its value during the conceding process. And if $r_A^j > e_A^j$, j is benefit-based type attribute, such as sale price of supplier agents. The greater, the better. So, negotiators will gradually decrease its value in the conceding process.

4) λ_A^j is the conceding mode of agent A. There are 4 types of conceding modes as below.

①when $\lambda_A^j = 0$, $P_{A \to B}^j(t) = P_{A \to B}^j(t-1)$, it means A will never concede.

②when $0 < \lambda_A^j < 1$, agent A will give large concession in the early stage，but smaller concession in the later stage. We call it *anxious mode*.

③when $\lambda_A^j = 1$, $P_{A \to B}^j(t) = P_{A \to B}^j(t-1) + \frac{r_A^j - e_B^j}{\tau}$. Constant concession will be made by agent A throughout the negotiation. The concession interval is $\frac{r_A^j - e_A^j}{\tau}$. We call it *constant mode*.

④when $\lambda_A^j > 1$, small concession in the early stage，but larger concession in the later stage. We call it *slow mode*.

5) If $P_{A \to B}^j(t)$, calculated by formula (3), is inferior to the reservation value r_A^j , $P_{A \to B}^j(t) = r_A^j$. This rule guarantees the proposed value will never be worse than the reservation value.

3.2. Conceding strategy considering the effect of argument

When considering the effect of argument, negotiators will adjust the proposed value

based on the original value $P_{A \to B}^{j}(t)$, and get the new proposed value $P'^{j}_{A \to B}(t)$. Formula (4) gives the algorithm.

$$P'^{j}_{A \to B}(t) = P_{A \to B}^{j}(t) + M_{A \to B}^{j}(t) \qquad (4)$$

3.3. A calculation example

The following example explains our proposed adjusting conceding strategy.

Suppose that, A is a purchaser agent, and B is a supplier agent. They have only one item to negotiate, price. The reservation value of price for A is $r_A^{price} = 100$, and expectation value is $e_A^{price} = 80$. The time of negotiation is expressed by negotiation round here. Set $\tau_a = 20$, which means the negotiation will terminate even if there is no agreement up to 20 rounds. Given that, $P_{A \to B}^{price}(4) = 85$. At round 5, agent A receives a proposal $O_{B \to A}^{price}(t) = 95$ from agent B, which is supported by an argument explaining the reason of the proposal. Agent A evaluates the strength of the argument, $Strength(A_{B \to A}^{price}(5)) = 0.8$.

So, for A, how much will he propose in the next round? It will calculated by the following three steps.

1) According to Formula (3), calculate the

$$P_{A \to B}^{price}(5) = 85 + (100 - 80)\frac{5^{\lambda_A^{price}} - 4^{\lambda_A^{price}}}{20^{\lambda_A^{price}}}$$

time-constraint proposal value $P_{A \to B}^{price}(5)$.

Suppose agent A adopts *constant mode* strategy, $\lambda_A^{price} = 1$, then:

$$P_{A \to B}^{price}(5) = 85 + \frac{1}{20}(100 - 80) = 86$$

2) According to Formula (1), calculate the revision value $M_A^{price}(5)$. Due to B's proposal value $O_{B \to A}^{price}(t) = 95$ is between r_A^{price} and $P_{A \to B}^{price}(5)$, the calculation is as follows.

$$M_A^{price}(5) = (O_{B \to A}^{price}(5) - P_{A \to B}^{price}(5)) \times Strength(A_{B \to A}^{price}(t)) \times \varepsilon$$
$$= (95 - 86) \times 0.8 \times \varepsilon$$

Set $\varepsilon = 0.5$, then:

$$M_A^{price}(5) = (95 - 86) \times 0.8 \times 0.5 = 3.6$$

3) According to Formula (4), calculate the adjusted proposal value $P'^{price}_{A \to B}(5)$.

$$P'^{price}_{A \to B}(5) = 86 + 3.6 = 89.6$$

4. Experiment analysis

4.1. Problem description

In supply chain environment, agent A is negotiating with agent B on the price of some product. A is the buyer and B is the supplier. A, as well as B, has its goal structure, shown in table 1. The deadline time is 10 ($\tau_A = \tau_B = 10$).

Item	A		B	
	e_A^{price}	r_A^{price}	e_A^{price}	r_A^{price}
Price	600	800	950	750

Table 1: Origin goal of A and B.

Strategy：A use our proposed strategy, CSBOTCAAE, to make concession during negotiation. B use time-constraint strategy, which is the same conceding mode with A. In detail, if A use slow mode, B will use slow mode either; if A use constant mode, B will use constant mode either.

Protocol：A gives bid first. B will evaluate the proposal using the following rules.

1) If the price proposed by A is not higher or equal to the will-be-proposed price by B, B will accept the price and negotiation succeeds.

2) Otherwise, B will determine its proposal value based on its time-constraint strategy.

3) If the deadline has come with no agreement reached, the negotiation failed.

4.2. Negotiation process

We will consider two different conditions: In the first condition, there is no argument used by each negotiator. And in the second circumstance, B will use argument during negotiation, and A will use our proposed strategy to deal with the argument.

4.2.1 Condition one (no one use argument during negotiation)

In this circumstance, we assume three types of conceding mode, anxious (let $\lambda_A = 0.5$), average($\lambda_A = 1$), and slow(let $\lambda_A = 2$) , are respectively applied by A and B. And as has been regulated, the conceding mode of A and B are always the same. Then the price of each time proposed by A, as well as B, is shown in table 2.

	Buyer A			Supplier B		
t	λ_A			λ_B		
	2	1	0.5	2	1	0.5
0	600	600	600	950	950	950
1	602	620	663	948	930	887
2	608	640	689	942	910	861
3	618	660	710	932	890	840
4	632	680	726	918	870	824
5	650	700	741	900	850	809
6	672	720	755	878	830	795
7	698	740	767	852	810	783
8	728	760	779	822	790	779
9	762	780	—	788	780	—
10	800	—	—	800	—	—

Table 2: Negotiation process in 3 conceding modes.

Figure 1 illustrates the conceding process when $\lambda_A = 0.5$, figure 2 illustrates the conceding process when $\lambda_A = 1$, and figure 3 illustrates the conceding process when $\lambda_A = 2$.
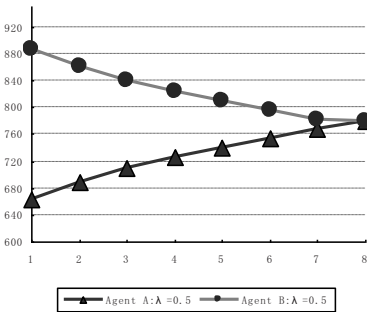

Fig. 1: Negotiation process without argument when $\lambda_A = 0.5$.
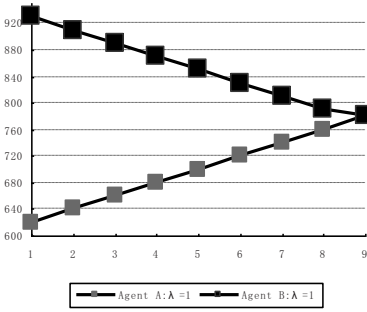

Fig. 2: Negotiation process without argument when $\lambda_A = 1$.

The final result and agreement price in three modes will be: 800 ($\lambda_A = 2$, $t_{\text{deal}} = 10$) , 780 ($\lambda_A = 1$, $t_{\text{deal}} = 9$) , 779 ($\lambda_A = 0.5$, $t_{\text{deal}} = 8$) . tdeal is the time when the negotiation succeeds.

4.2.2. Condition two (B use argument, and A use the proposed revision conceding strategy)

Assume that, when t=4, A receives a proposal from B, $O_{B \to A}^{price}(4)$. The proposal is accompanied with a relevant argument to explain the reason. After evaluation,

$Strength(A_{B \to A}^{price}(4)) = 0.8$, and let $\varepsilon = 0.8$. According to formula (1) and (4), $P_{A \to B}^{price}(4)$ will adjust from original $632|_{\lambda=2}$, $680|_{\lambda=1}$, $726|_{\lambda=0.5}$ to $752|_{\lambda=2}$, $764|_{\lambda=1}$, $772|_{\lambda=0.5}$, shown in table 3.
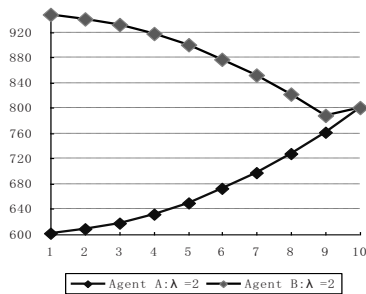

Fig. 3: Negotiation process without argument when $\lambda_A = 2$.

	λ_A		
	2	1	0.5
$O_{B \to A}^{price}(4)$	932	890	840
$P_{A \to B}^{price}(4)$	632	680	726
$M_A^{price}(4)$	120	84	46
$P'^{price}_{A \to B}(4)$	752	764	772

Table 3: Proposal adjusting at round 4.

	Buyer A			Supplier B		
t	λ_A			λ_B		
	2	1	0.5	2	1	0.5
4	752	764	772	918	870	824
5	770	784	787	900	850	809
6	792	800	800	878	830	800
7	800	800	—	852	810	—
8	800	800	—	822	800	—
9	800	—	—	800	—	—

Table 4: The negotiation process after round 4.

After round 4, each negotiator will follow their former conceding strategy.

The succeeding negotiation process is listed in table 4.

Figure 4 illustrates the conceding process when $\lambda_A = 0.5$, figure 5 illustrates the conceding process when $\lambda_A = 1$, and figure 6 illustrates the conceding process when $\lambda_A = 2$.
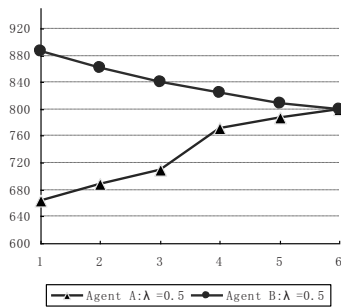

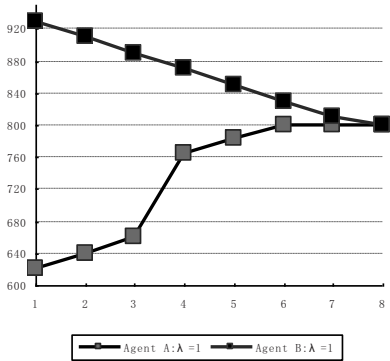Fig. 4: Negotiation process considering argument when $\lambda_A = 0.5$.

Fig. 5: Negotiation process considering argument when $\lambda_A = 1$.

As we can see from table 4, as well as figure 4, figure 5 and figure 6, the negotiation result is: 800 ($\lambda_A = 2$, $t_{deal} = 9$) ,800 ($\lambda_A = 1$, $t_{deal} = 8$) ,800 ($\lambda_A = 0.5$, $t_{deal} = 6$) .
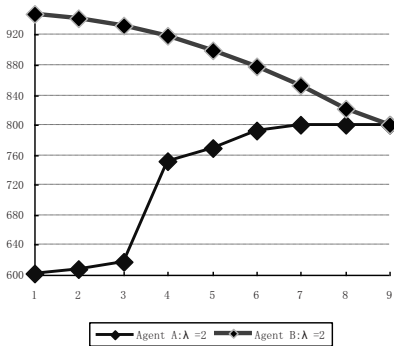
Fig. 6: Negotiation process considering argument when $\lambda_A = 2$.

4.3. Result analysis

From the result demonstrated in the above section, we can infer that:

1) Argumentation makes impact on *A*'s decision mechanism. Because *B* have applied effective argument in negotiation, the final agreement is more beneficial to *B* than *A*.

2) As for *A*, although the price is not the best, the negotiation time has been decreased, from original （10,9,8） to （9,8,6）, which imply that argument has the ability to improve the negotiation efficiency.

3) In our experiment, we apply relatively simple conceding mode, and we assume that the negotiators use the same mode. In the actual situation, different conceding mode may be made by the negotiators, but the result will be in the same tendency.

5. Conclusions

In argumentation-based negotiation, how argument affects the decision strategy is a research focus. In this paper, we provide a novel idea to consider this issue, and propose a conceding strategy based on time-constraint and argument-effect. Experiment validate the proposed model and strategy, and prove that argument can have some positive effect on negotiation. It will be propagation on the research of how the argument mechanism works on negotiation decision mechanism.

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