Selection of Adaptive Strategies on Main Agent's Attitude Based on Historical Learning

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Abstract—**To solve the problems of uncertainty and variability in the current automated commerce negotiation, the intelligence of agent is applied to the process of the commerce negotiation. We propose the adaptive negotiation strategies based on multi-agent negotiation by historical learning algorithm. During negotiation, the main agent, for example buyer agent, obtains historical information of the opponent, as seller, from the third party agent who stores the information of agents participated in and trade information, and then calculates the negotiation attitude values of the opponents by historical learning algorithm. Considering the information of the dynamic market environment, the main agent presents an appropriate strategy by employing the adaptive concession strategy function and the effectiveness evaluation mechanism. The research achievement of this paper is a foundation for developing a real-life Multi-agent-based commerce negotiation system in the future.**

Keywords-adaptive strategy; historical learning; negotiation attitude; multi-agent system

I. INTRODUCTION

E-commerce negotiation based on multi-agent is the general term of the activities performed by agents aiming to reach an agreement on concerned issues [1-2]. At present, negotiation strategy is one of main topics in the field of automatic negotiation, and it is also a method of maximizing the interests of main agent under the constraint of certain negotiation protocol [3]. Due to the asymmetry of information and dynamic change of environment during negotiation, the choice of negotiating strategy becomes the key factor of a successful negotiation. In recent years, the single negotiation strategy has been used more frequently in the agent-based electronic trading system; however, the negotiating strategy combining both the attitude of negotiating agent and the change of dynamic market environment is rarely studied relatively.

Nowadays, the E-commerce negotiation environment is faced with the problems of information incompleteness and finite rationality of E-commerce. For the main agent, there is a problem to be solved urgently, which is how to synchronously improve the existing negotiation strategy, learn and generate adaptive strategy automatically [4]. In related research, the concept of adaptive strategy based on argumentation is proposed by Rahwan et al. [5] [6]. The concession strategies, response strategies, the proposal strategies and relevant utility function are established for realizing adaptive negotiations [7]. Ren et al presented the dynamic adaptability is necessary for agent to negotiate in open and dynamic environment [4]. Adaptive strategy can be used to describe and define decision-making behavior of agent during the process. And agents perform the appropriate adaptive operation for different roles in different environments. This paper focuses on the discussion of the problem that chooses adaptive strategies based on attitude of main agent by historical learning algorithm. The background of negotiation is shown in Section II, the factors affected the adaptive strategy of main agent are shown in Section III, the generation of adaptive strategy of main agent is presented in Section IV, and then the conclusion is given in Section V.

II. BACKGROUD ASSUMPTIONS

Assumption 1. Agents of both sides are selfish, to pursue their own interests for negotiation purposes;

Assumption 2. Agents of both sides have the ability to learn;

Assumption 3. Agents of both sides can react to the impact of environment and the information of opponents;

Assumption 4. The time factor on the negotiation parties is valuable;

Assumptions 5. Agents of both sides have the sincerity to reach agreement by negotiation and there is no fraud in the negotiation process.

III. FACTORS OF ATTITUDE ADAPTIVE STRATEGY OF NEGOTIATING AGENT

A. Time factor

Utility theory is a fundamental theory of Western economics， which can provide support for decision makers in a decision-making process by obtaining utility values of an act [8]. During the negotiation, time is one of the most important factors affecting the agents' behaviors. Considering this fact, this paper employs a time-utility function to assess the effectiveness of negotiation time [9]. Some notations are defined as follows:

$U(t)$: denotes time utility;

t : duration of negotiations;

T_b / T_s : limited negotiation time of agent b/s;

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$T = \min(T_b, T_s)$: limited negotiation time of both;

σ : utility coefficient, $0 < \sigma < 1$.

The function $U(t)$ is defined as follows:

$$U(t) = 1 - \sigma\left(\frac{t}{T}\right) \quad (1)$$

With the growth of the time, the utility value is getting smaller and smaller, the chance of negotiation success is getting smaller and smaller.

B. Factor of Supply-Demand Relationship

In the real E-commerce trade environment, the number of sellers and buyers has a direct impact on supply-demand relationship. It would be beneficial to the sellers in the negotiation when the number of sellers is less than the number of buyers, and vice versa. Thus, a ration function of the number of buyers and sellers is employed to reflect the supply-demand relationship. The ration function is defined as: B_t / S_t denotes the number of buyers/sellers agent at time t; agent s/b denotes the seller/buyer agent; $C(t)$ is the value of supply-demand relationship at time t, which always reflects the market competition; the larger the value is, the more competitive the market will be. The function $C(t)$ is as follows:

$$C(t) = \begin{cases} S_t / B_t, & \textit{for agent s} \\ B_t / S_t, & \textit{for agent b} \end{cases} \quad (2)$$

C. Historical Learning of Negotiation

In the negotiating process, the negotiation agent knows neither the effectiveness to each other brought by their offers, nor the reasoning principles and constraints of opponent (seller agent), or whether an agreement could be achieved, etc.Thus, learning negotiation history of the opponents continuously is critical for a successful negotiation. The negotiation history can be derived from a third party agent. And the historical prices in the negotiation are taken as the standard in this paper, and then the negotiation attitude of the opponents (seller agents) can be learned from the variable-ration of their two most recent bids [10]. The method of calculating the attitude values of the opponents is discussed respectively, according to three different historical records (historical offers) (assuming that purchase records are stored in the array SP [ ]):

1) Two historical records of negotiation

$SP[K]$: The K-th offer of Agent s, and it is a recent negotiation within the current time. The value of opponent's attitude can be defined as:

$$\text{Attivalue} = SP[K] / SP[K-1] \quad (3)$$

2) Three negotiating history records

$$R_1 = (SP[K-1] - SP[K-2]) / SP[K-2] \quad (4)$$

$$R_2 = (SP[K] - SP[K-1]) / SP[K-1] \quad (5)$$

$$\text{Attivalue} = \begin{cases} R_1 / R_2, R_1 < 0 \textit{ and } R_1 \neq R_2 \\ 1 \qquad R_1 < 0 \textit{ and } R_1 = R_2 \end{cases} \quad (6)$$

3) Three more negotiating history records

$$\text{Attivalue}_k = \begin{cases} (R_1 / R_2 + \textit{Attivalue}_{k-1}) / 2, R_1 < 0 \textit{ and } R_1 \neq R_2 \\ 1 \qquad R_1 < 0 \textit{ and } R_1 = R_2 \end{cases} \quad (7)$$

In the algorithm above, (R_1 / R_2) means the rate of changes between two bids of the seller. In this paper, buyer agent is considered as the main agent, and wants to learn the seller agent's attitude of negotiation. It would be the same research if the seller agent is considered as the main agent.

D. The Attitude Functions of the Main Agent

The factors which affect the main agent's negotiation attitude include: time factor, supply-demand relationship factor, and the opponent's negotiation attitude. In the attitude function of the main agent, ψ is defined as the attitude value of the main agent; history means the history of the negotiating opponent obtained from a third party agent; ψ denotes the initial attitude value of the main agent. The attitude function is defined as follows:

$$\Psi = f(B_t, S_t, t, T, \text{history}) = \psi \times U(t) \times C(t) / \text{Attivalue} \quad (8)$$

Different negotiation attitude value of main agent corresponds to different attitude [11]:

1) $2 \le \Psi$ (Patient): The negotiation agent keeps its initial proposal, and it slowly increase or decrease the proposal to its retention until the negotiation time is up;

2) $0.5 < \Psi < 2$ (Calm): The negotiation agent changes its proposed value relatively stable in the whole process of negotiation;

3) $0 < \Psi \le 0.5$ (Eager): The negotiation agent rapidly increases or decreases to its retention in the early negotiation process, and it will keep the value until negotiation ends.

IV. THE GENERATION OF THE ATTITUDE ADAPTIVE STRATEGY BASED ON HISTORICAL LEARNING

In this paper, the whole negotiation process involves three entities: buyer agent, seller agent, third-party agent. Third-party agent stores the historical information of negotiation and agents' credibility, and processes requests from both agents. Before the negotiation, the buyer/seller agent requests a third party agent to provide opponent's trade information, which could be helpful in the output of their negotiation attitude values finally.

A. The Generation of Attitude Adaptive Strategy of Main Agent

With aforementioned historical learning and the attitude function of the main agent, an adaptive concession strategy function based on time-bound can be easily established [12]. Let:

$P(t)$: denotes the offer of the main agent at time t;

P_{bmin} / P_{smin} : is the buyer's/seller's minimum offer;

P_{bmax} / P_{smax} : denotes the buyer's/seller's maximum offer;

ψ_b / ψ_s : is defined as the value of negotiating attitude of buyer/seller at time t, and it equals to Ψ ;

$(t / T_b)^{\psi_b}$: is the concession factor;

$(P_{bmax} - P_{bmin})$: means concession interval.

The function $P(t)$ of intention offer is defined as follows:

$$P(t)=\begin{cases} P_{bmin}+(P_{bmax}-P_{bmin})\times(t/T_b)^{\psi_b}, & \textit{for agent b} \\ P_{smax}-P_{smax}-P_{smin}\times(t/T_b)^{\psi_s}, & \textit{for agent s} \end{cases} \quad (9)$$

Based on the aforementioned function of offer, an effectiveness evaluation mechanism is established. Let p denotes the time at which negotiation issues reached; k denotes the time discount factor of issues. The utility of the issues can be defined as [13]:

$$\rho=\begin{cases} (P_{bmax}-p)\times(k)^t, & \textit{for agent b} \\ p-P_{smin}\times(k)^t, & \textit{for agent s} \end{cases} \quad (10)$$

Given the above, a proposal selection mechanism can be established, of which

$P_{s\to b}(t)$: means the proposal of Agent s to Agent b at time t;

$P_b(t)$: the intention offer of Agent b at time t;

$\rho_b(t)$: the utility value of Agent b's intention bidding;

$\rho_{s\to b}(t)$: the utility value of Agent s's bid for Agent b at time t;

p^t: Agent b's anti-bid at time t.

Evaluation function of the proposal, which Agent b sends to Agent s at time t as follows:

$$Evaluate_b(P_{s\to b}(t),t)=\begin{cases} accept(b,s,P_{s\to b}(t)), & if\ \rho_b(t)<\rho_{s\to b}(t) \\ reject(b,s), & if\ \rho_b(t)>\rho_{s\to b}(t)\ and\ t=T \\ proposal\ set\ p^t=P_b(t), & if\ \rho_b(t)>\rho_{s\to b}(t)\ and\ t<T \end{cases} \quad (11)$$

The buyer agent could get the value of attitude from historical learning, and get the offer using concession strategy function given above. Then compare the utility of self-intention offer with the utility of seller agent's proposal $P_{s\to b}$ at time t. If the time discount factor of issues k>1, the later the time to reach an agreement the greater the profit will be, the agent b with the value of negotiating attitude $\psi_b \geq 2$ or $\psi_s \geq 2$ could get larger profit. If k<1, the earlier the time to reach an agreement the greater the profit will be, so the agent with $0<\psi_b<0.5$ could get larger profit. At time t, if $\rho_{s\to b}(t)>\rho_b(t)$, the buyer agent could accept the seller agent's offer, and then the negotiation succeeds; if $\rho_{s\to b}(t)<\rho_b(t)$, and the negotiation time is up, then the negotiation terminates. Or else, the buyer agent makes its intention offer $P_b(t)$ as the re-proposal p^t to the seller agent, repeat the process above until the negotiation succeeds or terminates.

B. Learning Algorithm for Attitude Adaptive Negotiation Strategy of Main Agent

Based on the theories mentioned above, negotiation learning algorithm process of buyer Agent b is shown in Figure. 1:

1) Initialization. The negotiating participants set could be denoted as A= {Agent b, Agent s}, of which Agent b is the negotiation initiator; Agent s is the negotiation respondent. Negotiation issues set G includes n issues, t=0 means that the negotiating parties are ready;

2) Before the first round of negotiation, Agent b sends request to the third party agent for the information queries of Agent s. After confirmation, Agent b could obtain the history information of Agent s;

3) Agent b gets the value of attitude of Agent s by learning the opponent's historical negotiating information;

4) Agent b could get its value of negotiating attitude by the attitude function of main agent;

5) Agent b could obtain the intention offer P(t) through adaptive concession strategy function;

6) Agent b sends negotiating request proposal(Agent b,t,G) to Agent s;

7) If Agent s refuses to accept the proposal or the waiting time exceeds T, then the algorithm turns to step 15） negotiation termination. Otherwise, execute the next step;

8) When Agent s receives the negotiating request of Agent b, it gives out its proposal(Agent s, t', G) for each issue;

9) Agent b evaluates the proposal of Agent s by employing the strategy evaluation function $Evaluate_b(P_{s\to b}(t),t)$, and makes a strategy choice;

10) If $\rho_b(t)<\rho_{s\to b}(t)$, Agent b accepts Agent s' quote, and then turns to step 14） negotiation succeed;

11) If $\rho_b(t)>\rho_{s\to b}(t)$ and t>T, then the algorithm turns to 15）negotiation termination. Otherwise, execute the next step;

12) If $\rho_b(t)>\rho_{s\to b}(t)$ and t<T, then Act= {re-proposal}, Agent b sends its intention offer which is obtained from the concession strategy function as re-proposal (Agent b, t'', G) to Agent s. If Agent s modifies its original offer, turn to 3） history study, or else turn to the step 13） confirms quote;

13) If Agent b confirms the offer of Agent s, and then Agent b chooses the Agent s, turn to 14） negotiation succeeds, or else turn to 15） negotiation termination;

14) Act= {accept}, the negotiation succeeds, the current proposal is accepted as the results of the trade;

15) Act= {reject}, the negotiation terminates.

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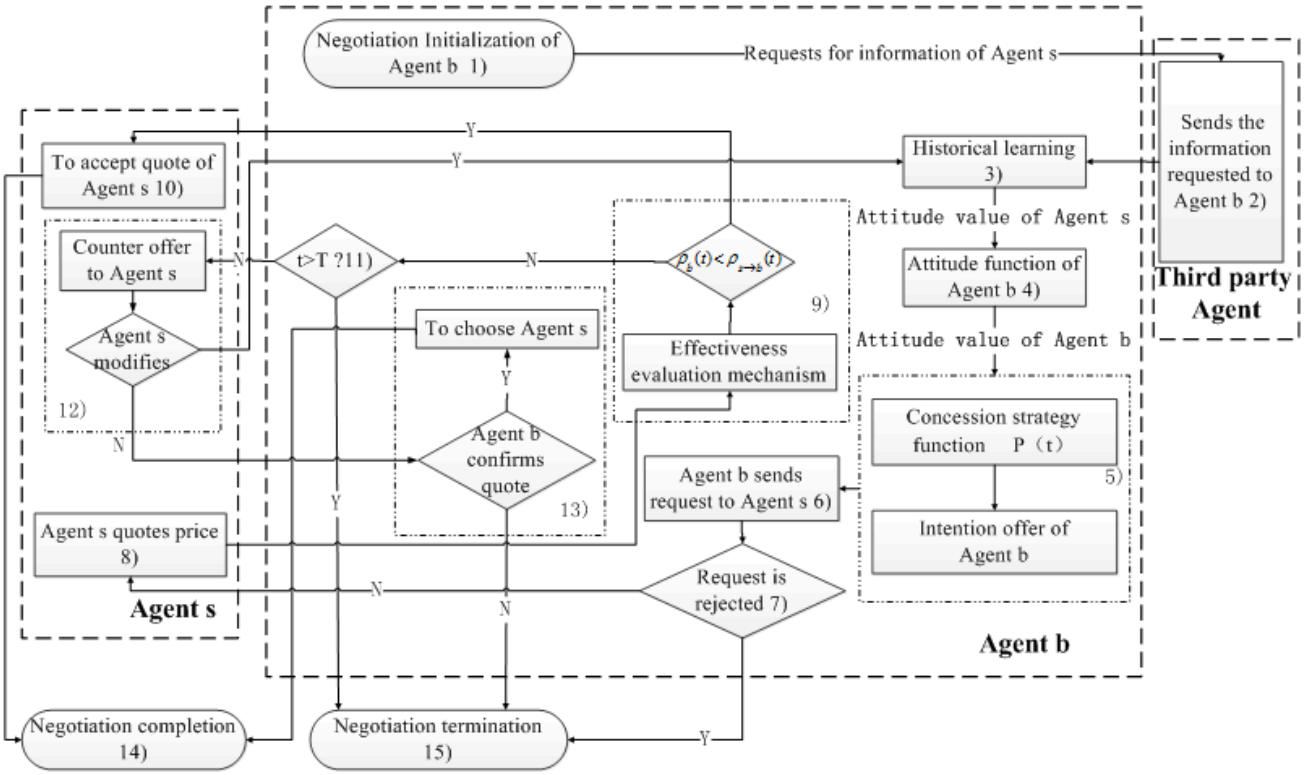

Figure 1. Negotiation learning algorithm process of agent b

V. CONCLUSIONS

The adaptive strategies play a very important role in the process of E-commerce automated negotiation for enhancing efficiency and arriving trade. Based on historical learning algorithm, an adaptive selection strategy based on attitude of main agent was proposed for solving the problems of uncertainty and variability in the current E-commerce negotiations. In this paper, the factors that can influence the adaptive strategy based on attitude of main agent were analyzed, the third-party agent was introduced, and a learning algorithm of the negotiator agent was also proposed.

The main agent could infer the opponent's attitude value by opponent historical information provided by the third party agent. It could also get its adaptive strategies by negotiation learning algorithm for considering the different attitudes of agents during negotiation process. The main agent could obtain its intention offer by the concession strategies, and then select a proposal by employing the evaluation mechanism of effectiveness to maximize its profit. By the theoretical analysis, it can be seen that the proposed algorithm could be efficiently applied to the "one-to-one "negotiation, as well as "one-to-many" negotiation. The proposed algorithm could help reduce the blindness of proposal and negotiation time, especially when the preferences or behaviors of the opponents are totally unknown during negotiation. Therefore, it has great help for increasing the successful rate of negotiation.

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