An Automated Multi-Issue Negotiation Mechanism Based on Intelligent Agents in E-Commerce

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***Abstract*—This paper presents an agent-based automated negotiation mechanism for multi-issue negotiation in e-commerce. To avoid a deadlock in which both agents are unwilling to concede or refuse to disclose more information may arise in the traditional alternating-offer pattern, the information of both agents is considered completely private. In our model, the issues are divided into two categories (i.e., continuous issues and discrete issues). To accelerate the negotiation process, we allow concurrent negotiation threads for different combination value of discrete issue. The seller agent and the buyer agent can only respond by varying the price in each thread. The mechanism can discourage counter-speculation and effectively control fraud and misrepresentation in a certain extent. Through a case study, the capabilities of the proposed method are illustrated and the mechanism could be well suited for practical applications.**

***Index Terms*—automated negotiation, multi-issue, e-commerce, mediator agent**

I. Introduction

Automated negotiation through autonomous agents is growing fast since the advent of e-marketplace. In recent years, bilateral automated negotiation has received considerable attention in the field of e-commerce [1], [2]. The simplest form of negotiation involves two agents and a single-issue [3]. However, in some cases, both agents prefer negotiate for multi-issue in a good deal of bilateral automated negotiations [4], [5]. Usually, a multi-issue negotiation is much more complex than a single-issue negotiation [6]. Humans, due to biases and limited information-processing capabilities, seldom perform effectively during negotiations [7], [8]. Thus, there are more studies on multi-issue negotiation in the AI(artificial intelligence) field in recent years [5], and agent-mediated automated negotiation has received considerable attention is in the field of e-commerce [9]. Moreover, a negotiation implemented by labor-saving and emotion-free automated agents in the e-marketplace may alleviate the difficulties inherent in human negotiations.

Several specific approaches to automated negotiation based on intelligent agents were introduced and investigated. The most known methods used to construct agents' negotiation model are game theoretic models, heuristic approaches and argumentation-based approaches. For an overview of these and other approaches we refer to Jennings *et al.* [10]. In addition, in the literature the difficulties with both agents simultaneously making concessions and searching for clever trade-off is generally avoided by assuming an mediator agent [11]. The mediator is inspired by the idea of a single negotiation text (SNT). SNT is a mediation device suggested by Fisher [12]. Ehtamo *et al.* [13] develop the method of the SNT method. However, both agents need to reveal their preferences to the mediator agent in these methods, hence trust becomes an important problem and they are not suit for the needs of the e-marketplace. In most realistic cases, an agent's beliefs about its opponent will not be known to its opponent. Ref [3] proposed a sealed-bid negotiation mechanism suited for e-commerce by introducing the mediator agent. Ref [14], [15] proposed a single-issue negotiation mechanism suited for application in e-commerce. Ref [4], [16] considered a specific negotiation model for multi-issue.

In this paper, we propose an agent-based sealed-bid mechanism for multi-issue negotiation from another perspective. Both agents submit their respective offer simultaneously to a third party by introducing a mediator in the proposed negotiation mechanism. To accelerate the negotiation process, we allow concurrent negotiation threads for different combination value of discrete issue. The thread in which the agreement is reached first determines the agreed price for the selected settings of the discrete issues. The mediator agent will only inform the other agent of the potential agreed price and the final acceptation or rejection messages by the opponents. This paper is organized as follows: first, the proposed agent-based sealed-bid negotiation protocol is presented. Then, a

Manuscript received July 3, 2014; revised October 30, 2014.

doi: 10.12720/joams.4.2.172-175

case study is given in the following section. Finally, we present the conclusion and outline some avenues for future work.

II. Negotiation Protocol

There are some definitions and notations which will be used in latter sections.

A. Two Different Cases about Multi-Issue

1) Negotiate on the whole price of multiple different goods:

In this case, we can bargain by taking the way of packing. Both negotiators could conduct the overall measure according to their respective importance of each good. Sequentially, the complex multi-issue negotiation could be converted to a single issue negotiation.

For example, both agents negotiate on the price of i different goods. Each agent a have a reservation price RP_a^i and a sincerity price SP_a^i about each good. Each agent will give a weight ω_a^i on each good. Then the whole reservation price RP_a and the whole sincerity price SP_a of each agent a could be calculated according to the following formulas:

$$RP_a = \sum_i \omega_a^i \cdot RP_a^i \ , SP_a = \sum_i \omega_a^i \cdot SP_a^i$$

2) Negotiate on multiple issues of one good:

In this case, both agents negotiate on different issues of singleton good. For example, negotiators may need to reach an agreement about the good that are characterized by some issues such as price, quality, delivery time, etc. Usually, the negotiators attach most importance to the price of the good, other issues can influence the price in a certain extent. The issues can be divided into two kinds according to different characteristics of each issue: continuous issue and discrete issue. An issue is continuous when the value can be varied any in an interval, such as price. The discrete issue can only be varied as some discrete points, such as delivery time etc.

In most cases, we could view the price issue as a class and other issues as the other class. Since the issues except the price are usually discrete, both agents can only negotiate the price issue for each combination value of other discrete issues. A value combination of all discrete issues determinate a negotiation thread. In the context of each thread, both agents can only respond by varying the price. In order to speed up the whole negotiation process, we can take multiple negotiation threads simultaneously and select a deal that reached first as final agreement result.

B. Assumptions and Notations

In our model, each agent has a value scope of the price in its own mind before starting the negotiation. Let $[IP_B, RP_B]$ and $[RP_S, IP_S]$ denote the price intervals of the buyer agent and the seller agent, respectively. RP_B denotes the reservation price of the buyer agent (i.e. the highest price that the Buyer agent is willing to accept) and RP_S denotes the reservation price of the seller agent (i.e. the lowest price that the seller agent can accept). IP_B denotes the lowest price that the buyer agent considers the seller agent will accept. Similarly, IP_S denotes the highest price that the seller agent considers the buyer agent will accept. In addition, each agent has a sincerity price SP_i in respective mind. Once there is $IP_B \le SP_S$ or $IP_S \ge SP_B$, the seller agent or the buyer agent will exit the negotiation.

Each agent has a time deadline. Let T_i denote agent i's time deadline, where $i \in \{B, S\}$ (B denotes the buyer agent, S denotes the seller agent). A protocol rule is that agents cannot backtrack and the negotiation continues until an agreement is reached or the time is expired. Let $p_i^t, i \in \{B, S\}$ denote both agents' offers at negotiation round $t, t \in \{0, 1, \cdots, \min\{T_B, T_S\}\}$. At negotiation round t, the mediator agent judges whether an agreement is reached according to the rule: $p_B^t \ge q_s^t$. If the agreement isn't reached, it informs both agents to enter the next round. Otherwise it begins to calculate the agreed price p according to the following formula: $p = \left(p_B^t + p_s^t\right)/2$, and informs both agents the agreed price. In this model, we assume the utility function of each agent is linear and is calculated as follows:

$$U_B(p) = \left(RP_B - p\right) \Big/ \left(RP_B - IP_B\right) \tag{1}$$

$$U_S(p) = \left(p - RP_S\right) \Big/ \left(IP_S - RP_S\right) \tag{2}$$

C. Producing New Offer

Since there is a time deadline on both agents, we assume that they use a time-dependent tactic for making a price concession. In these tactics, the predominant factor used to generate an offer next is negotiation round t. These tactics vary the offer depending on negotiation round t and agent i's time deadline $T_i, i \in \{B,S\}$. The offer $p_i^t, i \in \{B, S\}$ at negotiation round t are as follows respectively:

$$P_B^t = IP_B + \left(t \big/ T_i \right)^{1/\beta_B} \left(RP_B - IP_B\right) \tag{3}$$

$$P_S^t = IP_S - \left(t \big/ T_i \right)^{1/\beta_S} \left(IP_S - RP_S\right) \tag{4}$$

The parameter $\beta_i, i \in \{B, S\}$ is introduced in order to have different rates of offer concession [10]. We call that the agent follows a linear scheme when $\beta_i = 1$, conceder scheme when $\beta_i > 1$, and boulware scheme when $\beta_i < 1$. Fig. 1 shows three different patterns of behaviors for the buyer with price as an example [10].

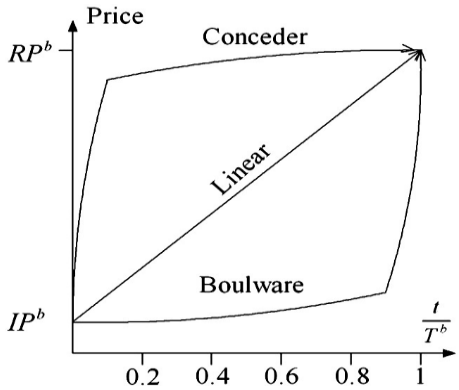

Figure 1. Three different offer patterns for the buyer agent.

III. Experiments Setup and Discussion

A. Experiments Setup

Without loss of generality, we consider a seller agent and a buyer agent that negotiate over the purchase of a specific product (e.g., a portable hard). Three negotiation issues exist for the two negotiators: price p, color c, delivery time t (i.e. the time required from the moment when an agreement is reached until the products are delivered to the buyer). We assume the portable hard is available in four colors: red, white, blue and black, and the delivery time t that the seller could provide consists of three discrete values: {3 days, 1 week, 10 days}. In this particular example we assume the buyer agent selects the color $c \in$ {red, blue, black} and delivery time $t \in$ {3 days, 1 week} based on its own preferences. Then there are six threads: {3 days, red}, {1 week, red}, {3 days, blue}, {1 week, blue}, {3 days, black}, {1 week, black}. Six threads start simultaneously. The thread in which the agreement is reached first determines the agreed price. The parameter settings of both agents in each thread are as follows:

$$RP_S = [193, 188, 210, 200, 200, 195]$$

$$IP_S = [265, 260, 275, 260, 260, 255]$$

$$T_S = 12,\ SP_S = 150\ ;\ T_B = 10, SP_B = 270$$

$$IP_B = [155, 150, 190, 160, 145, 140]$$

$$RP_B = [235, 220, 270, 260, 215, 210]$$

In addition, we assume each agent uses linear concession strategy in four threads, i.e. the concession rates of each agent are set as: $\beta_B = 1, \beta_S = 1$. By Eq. 3 and Eq. 4, we could calculate agent i's offer p_i^t.

TABLE I. The Proposed Negotiation Strategy

Negotiation round t	Both agents' offers (p_B^t, p_S^t) in six threads					
	Thread 1	*Thread 2*	*Thread 3*	*Thread 4*	*Thread 5*	*Thread 6*
0	(155,265)	(150,260)	(190,275)	(160,260)	(145,260)	(140,255)
1	(163,259)	(157,254)	*B* exits	(170,255)	*S* exits	*S* exits
2	(171,253)	(164,248)	_	(180,250)	_	_
3	(179,247)	(171,242)	_	(190,245)	_	_
4	(187,241)	(178,236)	_	(200,240)	_	_
5	(195,235)	(185,230)	_	(210,235)	_	_
6	(203,229)	(192,224)	_	(220,230)	_	_
7	(211,223)	(199,218)	_	(230,225)	_	_
8	terminate	terminate	_	agreement	_	_

Table I provides the offer process of the application of the proposed negotiation mechanism. According to the rule introduced earlier, the mediator agent will identify an agreement when $p_B^t > p_S^t$. From Table I, it can be seen that there is a first agreement at round $t = 7$ in the context of thread 4. According to the negotiation rule, the final agreed price is $p = \left(p_B^7 + p_S^7\right)/2 = (230 + 225)/2 = 227.5$. Then at round $t = 8$ in the context of thread 4, the mediator agent informs each agent that the negotiation ends with the agreed offer 227.5. But in other three threads, the mediator agent informs each agent that the negotiation will be terminated since an agreement is reached in the context of thread 4. That is, the agreement is reached first in the context of thread 4, the final agreed offer is {227.5, 1 week, blue}.

B. Discussion about Experiments Result

Each agent has a utility function $U_i(p), i \in \{B, S\}$, p is the agreed price. By Eq. 1 and Eq. 2, we calculate agent i's utility as follows:

$$U_B(p) = {(260-227.5)}\big/{(260-160)} = 0.325,$$

$$U_S(p) = {(227.5-200)}\big/{(260-200)} = 0.458$$

Two criteria which were suggested by Mumpower [17] were adopted to evaluate the negotiation model:

1) Efficiency

Efficiency is defined as nearness to the Pareto-frontier. We can modify the agreement to achieve a better payoff for one party necessarily implies a sacrifice on the part of the other for agreements falling on the Pareto-frontier. The efficiency of the agreement is measured as:

$$\text{Nearness} = \min\{d_1, d_2\}$$

where d_1 (or d_2) is the interval from the buyer (or seller) acceptable value to the Pareto-frontier.

In this case, we could calculate the efficiency as follows:

$$\text{The Nearness} = 0.017$$

It is very close to the Pareto frontier, i.e., the result of the experiment is nearly Pareto-efficient.

2) Equality:

This criterion is used to measure the fairness of a negotiated contract. It can be defined as:

$$\text{Equality} = |u_B(x) - u_S(x)|$$

where x is the negotiated contract. When the Equality equals zero, the contract is considered to be perfectly fair to both parties.

In this case, the $\text{Equality} = |0.325 - 0.458| = 0.133$, it is very close to zero, i.e., the outcome of the experiment is relatively fair.

IV. Conclusions

This paper presented an automated bilateral multi-issue negotiation mechanism which is suited for application in e-commerce. In our proposed mediated mechanism, the offer of each agent at each round is not revealed to the opponent. So, it greatly reduced the exchange of information between two agents to avoid strategic misrepresentations. This is what the e-commerce need. However, it is difficult for any mediated mechanism to completely prevent traders from eliciting information through the mediator about the private information of the opponent. We shall also consider this issue further in our future study.

Acknowledgements

This work was financially supported by the National Natural Science Foundation of China (71201050).

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