

# An Agent-based Multi-attribute Sealed-bid Design for Bilateral Contract

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**Abstract**—This paper presents an agent-based sealed-bid design for multi-issue negotiation in an incomplete information setting. The information of both agents is considered completely private. In our agent-based model, each agent builds a multi-dimensional fuzzy satisfaction set for the attributes of a commodity using fuzzy linguistic terms. The issues relating to an offer are divided into two categories (i.e., quantitative issues and qualitative issues). At each time-step of the negotiation, both agents submit a combined offer of quantitative issues for each discrete value of qualitative issue to the mediate agent simultaneously. This method offers flexibility for the agents represent their satisfaction for the combinations of different attributes using a multi-dimensional membership functions, taking into account the interdependencies between the attributes. In addition, using the proposed method of calculating agreed-price, agents can be stimulated to reach an agreement as early as possible. Therefore, this method may shorten negotiation process, which is desired for both parties. And the design 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.

**Index Terms**—bargaining, negotiation, sealed-bid, multi-issue, multi-agent systems

## I. INTRODUCTION

With rapid development of internet in the world, electronic commerce is growing fast. Automated negotiation by autonomous agents has become increasingly important since the advent of e-marketplace. In recent years, agent mediated negotiation has received considerable attention in the field of electronic commerce [1, 2]. Now, we can have multi-agent systems with software agents as brokers, sellers and buyers, which can negotiate and sign bilateral contracts for us. Moreover, the implementation of automated negotiations conducted by labor-saving and emotion-free software agents in the e-marketplace may alleviate the difficulties inherent in human negotiations.

Beam and Segev [3] classified automated negotiation into two major categories depending on an agent's learning ability. Agents in the first category have no learning ability and are initially created with a complete

set of strategies already in place. A well-known example of the use of agents of this type is the Kasbah e-marketplace created by Chavez and Maes [4]. At Kasbah, users provide agents with instructions detailing how the desired price is to be changed over a time frame. A review of other negotiation agents in this category can be found in Beam and Segev [3]. The second category of automated negotiation employs agents with learning abilities to acquire experience from previous negotiations. Learning mechanisms used in this type of automated negotiation include Bayesian theory, neural network learning, and genetic programming. As an example, Zeng and Sycara [5] modeled the negotiation process as a sequential decision making task, and used Bayesian probability to guess the opponent's reserved values. Hung [6] used supervised neural network learning to approximate the preference structure of an opponent such that the agent could calculate the similarity of its own offer to that of the opponent and could then counter-propose the most similar and beneficial offer. Genetic algorithms have also been applied to automated negotiations by some researchers. For example, Oliver [7] and Choi et al. [8] used genetic algorithms to find offers for agents to negotiate with one another.

For automated negotiation, it is important to design a framework that can also be the basis of negotiation software. Fatima et al. [9] investigated the design of reasoning mechanisms that enable agents to act competitively (obtain deals that are good for themselves) in service-oriented negotiations in which they have limited knowledge and computational resources. And Fatima et al. [10] presented a single-issue model for negotiation between two agents under time constraints and in an incomplete information setting by considering the agents' information as its private knowledge. Within this context, they determined optimal strategies for agents.

The simplest form of negotiation involves two agents and a single-issue. In Chen, Jeng, Lee, and Chuang [11] agent-based model for consumer-to-business electronic commerce is presented. They address the issues of synthesizing individual's preferences into a group's consensus, communication within the group, and collective negotiation. Usually the interactions among the agents in a multi-agent system are complex. Moreover, in most bilateral negotiations, the parties involved need to settle more than one issue. For example, agents may need

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to come to agreements about objects/services that are characterized by attributes such as price, delivery time, quality, reliability, and so on. One of the most well-known approaches adequate for multi-issue negotiations was proposed by Raiffa [12]. In his negotiation framework, win-win situations can be achieved, as one party's gain increase does not necessarily lead to increases on another party's losses. Additionally, Raiffa has addressed various aspects of multi-issue negotiations such as: utility functions, negotiation agendas, tradeoffs, strategic misrepresentations, etc. However, it has been argued in the literature [10] that Raiffa's framework is based on several implicit assumptions that, even though they may lead to good optimization results, they are inappropriate for the needs of the e-marketplace. Such issues are the following: Privacy of information for the negotiators is not supported; The utility function models must be disclosed; The value regions for the contract issues for both parties must be identified in advance; The only parameters that determine the utility of the contracts for the negotiators are the values of the issues under negotiation. Moreover, the vast majority of this work has assumed that negotiation issues are independent [13, 14, 15, 16], so agents can aggregate the utilities of the issue values by simple summation, producing linear utility functions. Many real-world negotiation problems, however, involve interdependent issues. When designers work together to design a car, for example, the value of a given carburetor is highly dependent on which engine is chosen. The addition of such interdependencies greatly complicates the agent's utility functions, making them nonlinear, with multiple optima. The attribute interdependencies are considered in several research works in different ways. Some assumed nonlinear utility functions for agents [17, 18], Lin and Chou [19] has explored a range of protocols based on mutation and selection on binary contracts. Barbuceanu and Lo [20] presents an approach based on constraint relaxation. Luo et al. [21] also presents constraint based approach. In addition, several papers used hierarchical models for multi-attribute goods, such as tree representation model [22, 23].

In related research literature, the interactions among the parties follow mostly the rules of an alternating sequential protocol in which the agents take turns to make offers and counter offers [24]. And all models are nearly built on the assumption that information about the uncertain parameter (in the form of possible values and a probability distribution over them) is the agents' common knowledge. However, in most realistic cases, an agent's beliefs about its opponent will not be known to its opponent. So, the alternating-offer game has at least two shortcomings. One is that both agents are unwilling first to offer because they worry that first bid may lose the better deal opportunity. Other shortcoming is that both agents are unwilling to concede on the negotiation because they are fear that an early concession reveals weakness and opens the door to exploitation by the opponent. The compounded result of the two effects is very inefficient outcome. Therefore, alternating-offer

may consume more time and cause a lower efficiency in some cases.

Now, we consider the bargaining situation of two persons, a seller and a buyer, negotiating over the price of an indivisible good that may be exchanged between the two. One mechanism that has been proposed for this setting, apart from the commonly used, face-to-face, open-ended bargaining familiar to us all, is the sealed-bid double auction. Each trader submits an offer and, if the buyer's bid is at least as large as the seller's ask, then the item is sold at a price between the two offers. If the offers do not overlap, then no trade takes place and the negotiations are broken off. This mechanism is first modeled by Chatterjee and Samuelson [25], and then studied in more detail by Myerson and Satterthwaite [26], Leininger et al. [27]. In these papers, incomplete information of the buyer and seller is modeled by assuming that the reservation prices of both traders are random variables with a joint probability distribution which is assumed to be common knowledge. However, the assumption usually is not able to be maintained in real applications.

In this paper, we propose an agent-based sealed-bid design in the Artificial Intelligence field. In this protocol, both agents submit their offers simultaneously to a third party by introducing the mediator. The mediator's role is mainly to shield bilateral offers and supervise the process of the negotiation. As soon as the seller's price bid is as great as the buyer's, the mediator announces agreement and the game ends with trade at the agreed price. Mediation is an effective procedure to decrease the inefficiency of alternating-offer bargaining because the filtering of information through a mediator cancels the worry of both traders. With face to face bargaining ruled out, agents are protected from exploitation and can therefore concede at the (constrained) optimal speed that allows the realization of all gains from trade.

Like Kebriaei and Majd [28], we use a multi-dimensional membership function represent the agent's satisfaction of different attributes for each point of the multi-dimensional attribute space. The difference from Kebriaei and Majd is that we consider the integral satisfaction of different issues by dividing the issues into two categories. Kebriaei and Majd [28] do not consider the classification. In our design, the issues relating to an offer are divided into two categories (i.e., quantitative issues, whose values can be measured on a numerical scale, and qualitative issues, which can only be assigned nominal values). Since the nature of the quantitative and qualitative issues is different, the satisfaction measures designed for these two categories must also be different. For each discrete value of qualitative issue, agents bargain on remain quantitative issues. At each step, both agents submit an offer for each discrete value of qualitative issue to the mediate agent simultaneously, and the mediate agent will only inform the other party of the potential agreed price and the final acceptance or rejection messages by the opponents. We then apply our model for buying a product and show the capabilities and different features of our design through simulation.

This paper is organized as follows: In Section 2, the negotiation architecture is presented. In Section 3, the proposed agent-based sealed-bid negotiation model is presented. The case study is given in Section 4. Finally, Section 5 gives some conclusions and suggests some topics for future research.

## II. NEGOTIATION ARCHITECTURE

In order to create a successful negotiation framework, the design of an appropriate protocol that will govern the interactions between the negotiation participants is necessary. Depending on the specific negotiation problem that needs to be solved, a protocol is the set of rules that correspondingly constrain the proposals that the negotiation parties are able to make. In this section, we will discuss the different components of the negotiation.

### A. Actors of Negotiation

Three actor agents of the sealed-bid design are as follows: the buyer  $B$ , the seller  $S$  and the mediator  $M$ . The seller prefers a high price to sell his good or service. On the contrary, the buyer exactly prefers a low price. The role of the mediator is to realize the sealed-offer simultaneous bargaining protocol, the most important feature of the mediator is to guarantee fair but not be partial to any party. According to the reciprocal rules prescribed by the sealed-bid negotiation, the mediator is responsible to monitor the progress of the entire bargaining process. In the bargaining process, both sides don't know the bids of the opponent. In the situation, they could rest assured to submit their offers to the mediator but don't need to fear that the exposition of the information may create the outflow of the potential payoff. The mediator is responsible to monitor the negotiation progress and shield the bid information of both agents. The main responsibility of the mediator has the following several aspects:

1) The initialization of the negotiation. Any of both agents could propose the request for initialization, but the initialization must be completed by the mediator. The work includes the confirmation of legal identity of both agents and the information collection for new bargaining conversation, such as the marks of the participants, the denomination of the commodity, the starting time, etc.

2) Supervise the negotiation acts of both sides. The acts of both agents have to conform to the rule that the negotiation stipulated, otherwise the mediator will send out the warning information. For example, the participant cannot submit the same offer in next round and the new bids must be submitted toward the direction that can shorten the negotiation process, etc.

3) Judge whether the trade succeed or not. The mediator contrasts the offers after he received the offers of both sides. Once the offer of the buyer agent is higher than or is equal to the offer of the seller agent, the mediator inform both agents that the trade succeeds immediately. Otherwise, the mediator sends both sides the negotiated outcome of this stage and inquires that whether the negotiation to continue.

4) Terminate the negotiation. When the trade succeeds

or one party withdraw from the negotiation halfway, the mediator terminates the negotiation and records the time the negotiation is over and the outcome of the negotiation.

### B. Negotiation Steps

To start and execute a negotiation process in the sealed-bid design, the following steps are necessary:

1) Initially, all users have to register with the marketplace to create their own agents for selling or buying on the server.

2) An agent created by a user contacts a mediator agent. The mediator is a centralized "super-agent", handling the agents' communication. The agent's database now contains information about active agents, e.g. agent type (sell/buy agent), deadlines, addresses, etc.

3) After receiving initial offers from buy and sell agents the mediator checks whether the offers are compatible. If the offers are compatible, the mediator will inform both sides that the negotiation ends with agreement and the final agreed-price. Otherwise, the mediator returns the negotiation outcome to both agents and informs them to ready for submitting next offers.

4) In time-step  $t$ , the mediator has following three acts: If the buyer's price bid is higher than the seller's, the mediator announces agreement and calculates the agreed price. The game ends with trade at the agreed price and the negotiation is terminated; If the buyer's price bid is lower than the seller's, then the negotiation enters next round; If one agent send the mediator the terminated information, then the mediator inform both sides that the negotiation is terminated.

5) After several rounds of simultaneous offers and requests, the negotiation process will end with an agreement between sell and buy agents in the ideal case. The mediator will update the databases.

### C. Negotiation Process

To further facilitate signing of bilateral contracts among the agents, we use the idea introduced in Faratin et al. [10] for time-constrained negotiation method, which allows agents to have flexible negotiation based on their heuristics. If any feasible agreement is met, a bilateral contract is signed accordingly. An agent can negotiate with more than one issue simultaneously. The negotiation constraints are the deadline of each agent, the market deadline for negotiation duration. At each time-step of bargaining process, agents concede their satisfaction degrees by adapting their membership functions. The introduced concession rate is based on different agents' preferences and heuristics, which is inspired from the work of Faratin et al. [10]. The proposed procedure stops when the market deadline is over. The design scheme of the proposed method is shown in Fig. 1 [28].

### D. Utility Functions of Agents

In this study, the buyer's/seller's utility function for a contract considers a linear additive model incorporating the utilities of each contract issue that is involved in the negotiation. In essence, we assume that the various issues are substitutes, e.g. price and quality. Linearity can also be a result of assuming risk neutral agents [29]. However,

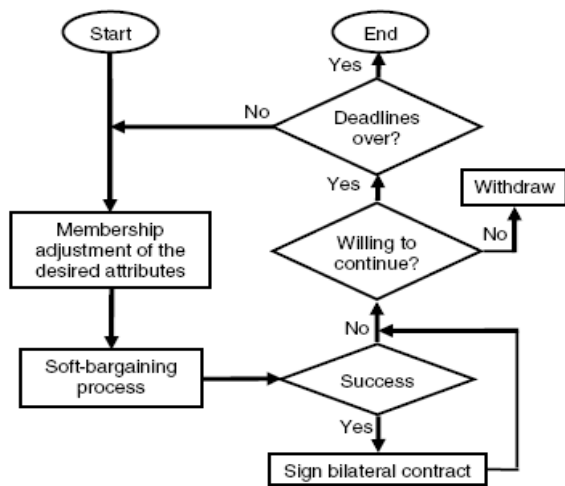


Figure 1. Design scheme.

it should be noted that the utility function of each individual contract issue may be of any continuous and monotonic functional form, either concave or convex (e.g., linear, polynomial, exponential, multiplicative, quasi-linear, etc.) of the contract issue value and the decision issue value at the time the contract is proposed, without affecting the basic ideas of our proposed negotiation model and strategies.

We take the utility function of price as an example. Here we adopt what is basically a mediated bargaining game enriched in a standard way with reservation prices (i.e., the maximum price at which the buyer would buy the item and the minimum price at which the seller would sell it) and deadlines (i.e., time points after which the buyer or the seller have no more interest in bargaining). The utility derived by agents depends on the final agreement on the price and the duration of negotiation. However, utility from price to an agent is independent of its utility from time, i.e., the buyer always prefers a low price and the seller always prefers a high price. Thus:

$$U_a : P \times T \rightarrow \mathfrak{R} \quad a \in \{B, S\}.$$

Let  $U_a(p, t)$  denotes agent  $a$ 's utility function, i.e.,  $U_a(p, t)$  represents agent  $a$ 's gain from an agreement on the value  $p$  reached at time  $t$ . The utility of the seller increases linearly with  $p$ , while the utility of the buyer decreases linearly. Each agent  $a$  has a bargaining time deadline, after which her utility function becomes negative. Let  $T_a$  denotes agent  $a$ 's deadline where  $T_a \in T$ . Agents' utilities are defined with the following von Neumann–Morgenstern utility function that incorporates the effect of time discounting:

$$U_a(p, t) = U_a^p(p) U_a^t(t),$$

$U_a^p(p)$  and  $U_a^t(t)$  are unidimensional utility functions. Here, preferences for attribute  $p$ , given the other attribute  $t$ , do not depend on the level of  $t$ .  $U_a^p$  is defined as:

$$U_a^p(p) = \begin{cases} RP_B - p & \text{for the buyer,} \\ p - RP_S & \text{for the seller.} \end{cases}$$

$U_a^t$  is defined as  $U_a^t(t) = (\delta_a)^t$ , where  $\delta_a$  is the discounting factor. Agent  $a$ 's utility from conflict is defined as  $U_a(C) = 0$ . Agents can aggregate the utilities of the issue values by simple summation, producing linear utility functions as the integral utilities of agents.

### III. NEGOTIATION MODEL

In many of the applications that are conceived in the domain of e-commerce, it is important that the agents should not only bargain over the price of a product, but also take into account issues such as the delivery time, quality, payment methods, and other product specific properties. We divide these issues into two categories: quantitative issues and qualitative issues. Examples of quantitative issues include price, delivery time, penalties, etc., while examples of qualitative issues include quality, color, etc. The satisfaction measures designed for these two categories must also be different. We discuss a protocol based on a ranking mechanism on the buyer's side, which is adopted in the context of this study.

#### A. Satisfaction Measures for Quantitative Issues

Let us take the price as an example. We use  $RP_B$  and  $IP_B$  to denote the buyer's reservation value (maximum affordable price for buyer) and initial value (minimum acceptable price for seller that buyer considered) of price issue, respectively;  $RP_S$  and  $IP_S$  denote the seller's reservation value (minimum affordable price for seller) and initial value (maximum acceptable price for buyer that seller considered) of price issue, respectively. Let  $T_B$  denotes the buyer's deadline, and  $T_S$  denotes the seller's deadline. A value for offer of price issue that is acceptable to both buyer and seller (i.e., the zone of agreement) is the interval  $[RP_S, RP_B]$  and  $RP_B - RP_S$  is known as the price-surplus. The buyer's initial price,  $IP_B$ , has a value less than the seller's reservation price  $RP_S$ . Similarly, the seller's initial price  $IP_S$  has a value greater than the buyer's reservation price  $RP_B$ . In other words, both  $IP_B$  and  $IP_S$  lie outside the zone of agreement. Otherwise they are impossible to achieve agreement.

Since both agents have a deadline, we assume that they use a time dependent tactic (e.g. linear (L), Boulware (B) or Conceder (C)) [9] for generating the offers. In these tactics, the predominant factor used to decide which value to offer next is time. The tactics vary the value of issue depending on the remaining negotiation time. The offer of each issue made by both agents at time  $t$  is modeled as a function depending on time  $t$ .

We still take the price as an example. The price bid function for the buyer  $p_B(t)$  is an increasing function versus time, varying from  $IP_B$  to  $RP_B$ , and the price bid

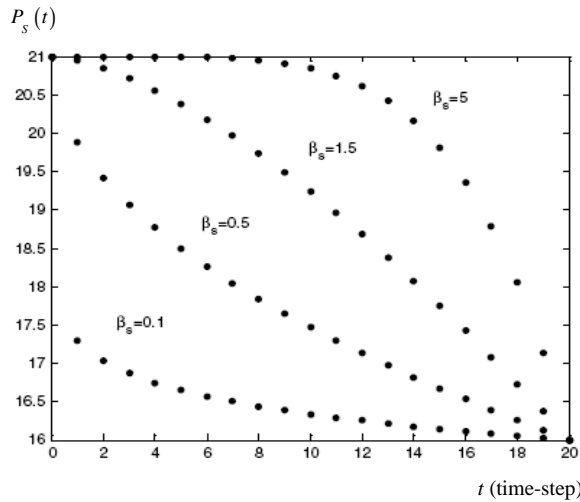


Figure 2. Different strategies by variation of parameter  $\beta_s$  ( $IP_s = 21$ ;  $RP_s = 16$ ).

function for the seller  $p_s(t)$  is a decreasing function versus time, varying from  $IP_s$  to  $RP_s$  during bargaining according to:

$$p_B(t) = IP_B + (RP_B - IP_B) \left(\frac{t}{T_B}\right)^{\beta_B}, \quad t \in \{0, 1, \dots, T_B\}, \quad (1)$$

$$p_S(t) = IP_S + (RP_S - IP_S) \left(\frac{t}{T_S}\right)^{\beta_S}, \quad t \in \{0, 1, \dots, T_S\}, \quad (2)$$

where  $t$  denotes the negotiation steps, positive  $\beta_B$  and  $\beta_S$  determine the buyer and seller's rate of concession for price, respectively. Fig. 2 shows  $p_s(t)$  during the bargaining process for different values of  $\beta_s$ . Other attributes such as delivery time can be defined analogously.

We evaluate the satisfaction measures of agents for quantitative issues by using membership function. The membership functions  $\mu_B(p)$  and  $\mu_S(p)$  for final-agreement price  $p$  should be chosen such that:

$$\ker(\mu_B(p)) = [0, RP_B], \quad \text{supp}(\mu_B(p)) = [0, IP_B],$$

$$\ker(\mu_S(p)) = [IP_S, \infty], \quad \text{supp}(\mu_S(p)) = [RP_S, \infty].$$

The functions  $\mu_B(p)$  and  $\mu_S(p)$  for both agents are defined as follows:

$$\mu_B(p) = \begin{cases} 1, & p \leq IP_B \\ \frac{RP_B - p}{RP_B - IP_B}, & IP_B \leq p \leq RP_B \\ 0, & p \geq RP_B \end{cases}, \quad (3)$$

$$\mu_S(p) = \begin{cases} 1, & p \geq IP_S \\ \frac{p - RP_S}{IP_S - RP_S}, & RP_S \leq p \leq IP_S \\ 0, & p \leq RP_S \end{cases}, \quad (4)$$

The membership functions of other attributes can be defined analogously.

### B. Satisfaction Measures for Qualitative Issues

In this case, we consider only the satisfaction measures of the buyer, since the seller is very clear about the characteristic of own commodity that the buyer is not very clear. We define the membership function directly over the finite set of qualitative values  $Q = \{q_1, q_2, \dots, q_r\}$  as:

$$\mu_B(q_i) : Q \rightarrow [0, 1], i \in \{1, 2, \dots, r\},$$

a discrete function over the domain of qualities.

### C. Integral Satisfaction Measures for Multi-issue

The next element of the model is how we evaluate the integral satisfaction measures of agents. Let  $I_i$  denotes issue  $i$ . According to the general fuzzy linguistic terms, the integral satisfaction measure of the buyer can be defined as follows:

$$\mu_B = \min \mu_B(I_i). \quad (5)$$

### D. Negotiation Rules

The simplest protocol, which minimizes the complexity of the rationale behind the decision models of the agents, specifies that the agents can only accept or reject others' proposals. Nevertheless, in complex cases where multiple issues are considered, this convention may lead to a very time-consuming and inefficient process, since the agents have no means to verify why the specific proposal is unacceptable, or towards which direction of the negotiation space they should move. Hence, the proposer is essentially offering contracts on the basis of his/her beliefs as to what the other party prefers. In order to improve on the efficiency of the negotiation process, we propose a sealed-offer simultaneous bargaining protocol.

The protocol adopted in the context of this study can be described as follows. For convenience, we assume that we have a market with a buyer and a seller, and that price and quality are the main two attributes in the decisions of the agents. Before starting the negotiation, the seller agent must submit the quality type  $(q_i, q_i \in Q = \{q_1, q_2, \dots, q_r\})$  of commodity that it could provide to the mediate agent, then the mediate agent inform to the buyer agent. Once both agents come to an agreement with the qualitative issue, then they begin to negotiate the price for each  $q_i$  simultaneously. At each time-step of the bargaining, agents submit their offer to the mediate agent using (1) and (2), respectively. And agents concede by adjusting their rate of concession  $\beta_B$  and  $\beta_S$ , respectively. The mediate agent is responsible to check whether bids are compatible or whether the time has surpassed the deadlines of both agents. If their bids are not compatible, then the mediate agent will only inform both agents rejection message and negotiation enters the next round. If  $t = \min\{T_B, T_S\}$ , then both agents will be informed the time expire and the negotiation terminate. Once their bids

are compatible, the mediate agent will compute the agreed price according to the following formula:

$$p = p_B(t) - \frac{p_B(t) - p_B(t-1)}{p_B(t) - p_B(t-1) + p_S(t-1) - p_S(t)} \cdot (p_B(t) - p_S(t)), \quad (6)$$

or

$$p = p_S(t) + \frac{p_S(t-1) - p_S(t)}{p_B(t) - p_B(t-1) + p_S(t-1) - p_S(t)} \cdot (p_B(t) - p_S(t)), \quad (7)$$

This indicates the agent whose concession is bigger will obtain more price-surplus  $p_B(t) - p_S(t)$ . This method may make negotiation process shorter, which is desired for both parties.

After the mediate agent inform both parties that their bids are compatible, the buyer agent use (5) to calculate the integral satisfaction measures  $\mu_B^i$  for each qualitative value  $q_i$ ,  $i \in \{1, 2, \dots, r\}$ . At last, the buyer agent chose the maximum satisfaction measures from  $\mu_B^i$  to sign bilateral contract with the seller agent, then they conclude a contract.

#### IV. CASE STUDY

In this section, a case study in bilateral contracts is presented to show the capability of the proposed bargaining method. We assume that a buyer and a seller are bargaining on a product, and that price and quality are the main two attributes in the decisions of the agents. The seller could provide the product with three different qualities. Let the finite set of quality be:  $Q = \{q_1, q_2, q_3\}$  ( $q_1$  denotes general quality,  $q_2$  denotes good quality, and  $q_3$  denotes very good quality).

The buyer and the seller have different reservation value and initial value for different quality, respectively. These initial conditions are given in Table I. The deadlines and the price concession rates for the agents are also given in Table I. We set the satisfaction measure of different quality for the buyer as:

$$\mu_B(q_1) = 0.2, \mu_B(q_2) = 0.35, \mu_B(q_3) = 0.25.$$

Three bargaining processes, namely  $(p_i, q_i)$  ( $i = 1, 2, 3$ ) begin simultaneously. Figs. 3, 4 and 5 show that the offer strategies of both agents for three kind of different quality.

Fig. 3 shows the agreement occurs at time-step 7 for  $q_1$ , Fig. 4 shows the agreement occurs at time-step 7 for  $q_2$ ,

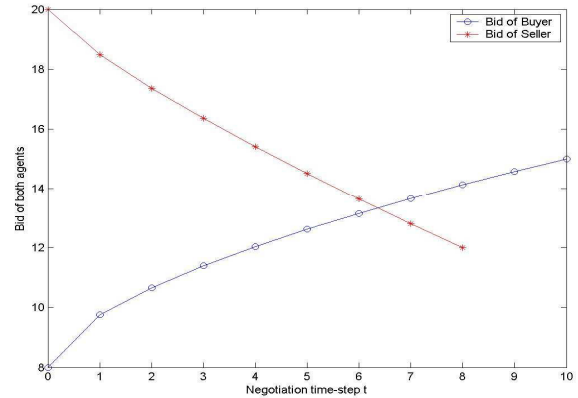


Figure 3. The strategies of both agents for quality  $q_1$ .

Fig. 5 shows the agreement occurs at time-step 6 for  $q_3$ . The mediate agent calculates the agreed-price with three kind of different quality using (6) or (7) as follows: for  $q_1$ , the agreed-price

$$\begin{aligned} p_1 &= p_{1B}(7) - \frac{p_{1B}(7) - p_{1B}(6)}{p_{1B}(7) - p_{1B}(6) + p_{1S}(6) - p_{1S}(7)} \cdot (p_{1B}(7) - p_{1S}(7)) \\ &= 13.651 - \frac{13.651 - 13.152}{13.651 - 13.152 + 13.645 - 12.811} \cdot (13.651 - 12.811) \\ &= 13.337; \end{aligned}$$

for  $q_2$ , the agreed-price

$$\begin{aligned} p_2 &= p_{2B}(7) - \frac{p_{2B}(7) - p_{2B}(6)}{p_{2B}(7) - p_{2B}(6) + p_{2S}(6) - p_{2S}(7)} \cdot (p_{2B}(7) - p_{2S}(7)) \\ &= 22.688 - \frac{22.688 - 21.832}{22.688 - 21.832 + 23.084 - 21.520} \cdot (22.688 - 21.520) \\ &= 22.275; \end{aligned}$$

for  $q_3$ , the agreed-price

$$\begin{aligned} p_3 &= p_{3B}(6) - \frac{p_{3B}(6) - p_{3B}(5)}{p_{3B}(6) - p_{3B}(5) + p_{3S}(5) - p_{3S}(6)} \cdot (p_{3B}(6) - p_{3S}(6)) \\ &= 36.832 - \frac{36.832 - 35.917}{36.832 - 35.917 + 37.641 - 35.701} \cdot (36.832 - 35.701) \\ &= 36.470. \end{aligned}$$

Then, the buyer agent calculates own satisfaction measure of different agreed-price with three kind of different quality using (3):

TABLE I. INITIAL CONDITIONS FOR BOTH AGENTS

Quality	Bid range of buyer ( $IP_B, RP_B$ )	Bid range of seller ( $RP_S, IP_S$ )	Price concession rate of buyer $\beta_B$	Price concession rate of seller $\beta_S$	Deadline of buyer $T_B$	Deadline of seller $T_S$
$q_1$	(8, 15)	(12, 20)	0.6	0.8	10	8
$q_2$	(13, 25)	(20, 35)	0.6	0.8	10	8
$q_3$	(28, 40)	(32, 50)	0.6	0.8	10	8

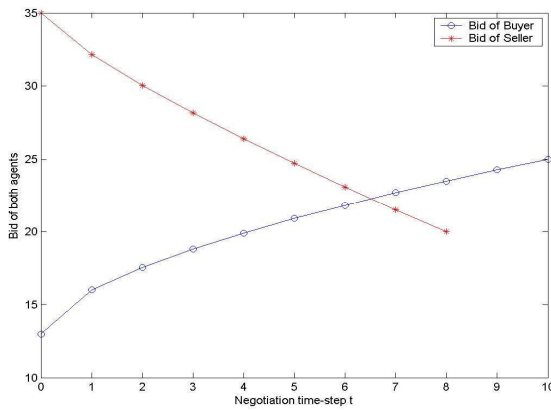


Figure 4. The strategies of both agents for quality  $q_2$ .

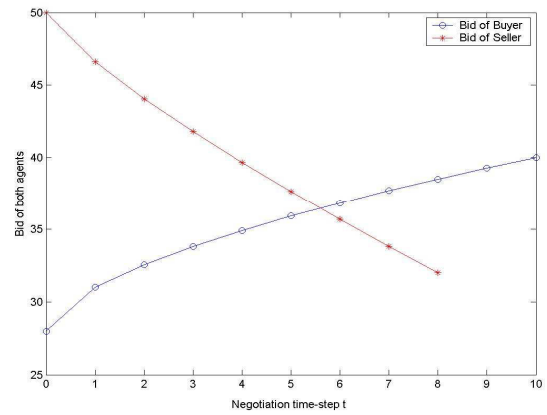


Figure 5. The strategies of both agents for quality  $q_3$ .

$$\mu_B(p_1) = \frac{RP_{1B} - p_1}{RP_{1B} - IP_{1B}} = \frac{15 - 13.337}{15 - 8} = 0.238,$$

$$\mu_B(p_2) = \frac{RP_{2B} - p_2}{RP_{2B} - IP_{2B}} = \frac{25 - 22.275}{25 - 13} = 0.341,$$

$$\mu_B(p_3) = \frac{RP_{3B} - p_3}{RP_{3B} - IP_{3B}} = \frac{40 - 36.470}{40 - 28} = 0.294.$$

With these data in place, the integral satisfaction measure of the buyer with three kind of different quality using (5) is calculated as follows, respectively:

$$\mu_B^1 = \min\{\mu_B(p_1), \mu_B(q_1)\} = 0.2,$$

$$\mu_B^2 = \min\{\mu_B(p_2), \mu_B(q_2)\} = 0.341,$$

$$\mu_B^3 = \min\{\mu_B(p_3), \mu_B(q_3)\} = 0.25.$$

As the results show, the agreement occurs at time-step 7 between the buyer agent and the seller agent. The final agreed-offer is 22.275(price) with good quality.

## V. CONCLUSIONS

Negotiation has long been recognized as a time-consuming process since all parties involved look to pursue their own interests in the face of conflicting goals. Alternating-offer bargaining protocol is the most predominant way for solving bilateral bargaining problem. However, the mutual suspicion of both traders causes the negotiation progress to slow down and the cycle to lengthen. E-commerce will strongly penetrate the market if coupled with appropriate technologies and mechanisms.

In this paper, an agent-based multi-attribute sealed-bid design for bilateral contracts is presented. In this protocol, both agents submit their offers simultaneously to a third party by introducing the mediator. With face to face bargaining ruled out, agents are protected from exploitation and can therefore concede at the optimal speed that allows the realization of all gains from trade. Each Agent builds a multi-dimensional fuzzy satisfaction

set for the attributes of a commodity. We use a multi-dimensional membership function to represent the agent's satisfaction of different attributes for each point of the multi-dimensional attribute space. The issues relating to an offer are divided into two categories (i.e., quantitative issues and qualitative issues). The agent chooses the maximum integral satisfaction measure from different quantitative values with qualitative issue to sign a bilateral contract.

The proposed protocol offers more flexibility in both offering and evaluating the proposals for signing bilateral contracts. Using the proposed agent-bargaining method, the consumer (buyer agent) will have flexibility for offering the proposals according to own demand as well as have more choices. In addition, using the proposed method of calculating agreed-price, agents can be stimulated to adjust their offers in a concession manner during negotiation to reach an agreement as early as possible. This method may shorten negotiation process, which is desired for both parties. It is important to emphasize that proposed bargaining method is carried out under incomplete information, and agents's information about own parameters (such as its reservation price or its preferences over issues, strategic behavior and so on) are considered completely private. The design 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.

In more realistic situation, agents have incomplete information about each other, and most of them are unwilling expose own information. We therefore presented an extended negotiation protocol that allows agents to negotiate through a mediator to satisfy their demand. We hope the method we proposed can be applied in real-world situations. However, this needs to more improvement in theory and practice. Especially, when the issues considered are too many, the implementation of software agent will become more complex. We need the finer method to apply to real-world situations. This is the direction we will study diligently in the future.

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