AN EFFICIENT NEGOTIATION STRATEGY IN E-COMMERCE CONTEXT BASED ON SIMPLE RANKING MECHANISM

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Abstract: Electronic commerce is expected to dominate the market if coupled with the appropriate technologies and mechanisms. Mobile agents are one of the means that may enhance the intelligence and improve the efficiency of systems in the e-marketplace. In this paper, we propose a dynamic multilateral negotiation model and we construct an efficient negotiation strategy based on a ranking mechanism that does not require a complicated rationale on behalf of the buyer agents. This strategy can be used to extend the functionality of autonomous agents, so that they reach to an agreement aiming to maximise their owner's utility. The framework considers both contract and decision issues, is based on real market conditions, and has been empirically evaluated.

1 INTRODUCTION

The last few years we have witnessed a rapid expansion of business carried out online. Thus, e-commerce has evolved to a field dominating present and future transactions. While current e-commerce systems offer advantages to both consumers and merchants, it is often the case that they offer little more than electronic catalogues on which credit card payments can be arranged online. One of the major changes expected in this environment is that dynamic pricing and personalisation of offers will become the norm for many transactions.

In order to harness its full potential and achieve the degree of automation required, a new technology is necessitated. Agent technology, which is already involved in almost every aspect of computing, seems to play a leading role, enabling a new, more flexible, generation of e-commerce systems. In such systems, automated software agents participate in trading activities on behalf of their owner. This paper is based upon the notion of interacting agents, which exhibit properties such as autonomy, reactivation, and pro-activation, in order to achieve particular objectives and accomplish the goals of their owners.

Mobile intelligent agents can act as mediators in five of the six e-commerce phases (He, 2003). This paper explores the role and behaviour of agents in the negotiation phase. Negotiation may be defined as "the process by which a joint decision is made by two or more parties. The parties first verbalise contradictory demands and then move towards agreement by a process of concession or search for new alternatives" (Pruitt, 1981). In human negotiations, the parties bargain to determine the price or other transaction terms. In automated negotiations, software agents adopt broadly similar processes to achieve the same end. When building an autonomous agent that is capable of flexible and sophisticated negotiation, three broad areas need to be considered (Faratin, 1998): (i) what negotiation protocol and model will be adopted, (ii) what are the issues over which negotiation will take place, and (iii) what negotiation strategies will the agents employ. The negotiation protocol defines the "rules of encounter" (Rosenschein, 1994) between the agents. Then, depending on the goals set for the agents and the negotiation protocol and model, the negotiation strategies are determined. Given the wide variety of possibilities, there is no universally best approach or technique for automated negotiations (Jennings, 2001), rather protocols and strategies need to be set according to the prevailing situation.

This paper concentrates predominantly on the first issue, proposing a negotiation protocol to be employed in an automatic multi-lateral, multi-step negotiation model and on the third point by providing an efficient negotiation strategy for the electronic Business-to-Consumer marketplace (a highly competitive environment). In this framework, the roles of the negotiation agents may be classified into two main categories that, in principle, are in conflict. Thus, the negotiating agents may be divided into two subsets: The Buyer Agents (BAs) and the Seller Agents (SAs), which are considered to be self-interested, aiming to maximise their owners' profit. The authors exploit a multi-round negotiation mechanism, which demonstrates inherent computational and communication advantages over single step mechanisms in such complex frameworks (Conitzer, 2003). In essence, the agents hold private information, which may be revealed incrementally, only on an as-needed basis. The negotiation environment considered covers multi-issue contracts and multiparty situations, while being a highly dynamic one, in the sense that its variables, attributes and objectives may change over time. Considering the case where SAs and/or BAs face strict deadlines, an effective negotiation strategy is proposed assisting all agents to reach to an agreement within the specified time-limits. In comparison to a more simplified negotiation strategy recently designed by the authors (Louta, 2004), the strategy presented hereafter demonstrates improved performance with respect to time and communication resources required.

The rest of the paper is structured as follows. In Section 2 the negotiation protocol & model adopted are presented. Section 3 elaborates on the designed negotiation strategy, which is adequate for cases where the rationale of the BAs is limited. Finally, in Section 4 conclusions are drawn and directions for future plans are given.

2 NEGOTIATION PROTOCOL & MODEL

In subsection 2.1, the negotiation protocol adopted is presented, which does not employ the alternating sequential offers pattern, but instead uses a contract ranking mechanism. Subsection 2.2 elaborates on the proposed negotiation model, which introduces the decision issues concept. A more detailed version of the proposed negotiation protocol and model is presented in (Roussaki, 2004).

2.1 Negotiation Protocol

In relative research literature, the interactions among the parties mostly follow the rules of an alternating sequential protocol in which the agents in turn make offers and counter offers (e.g., Rubinstein, 1982). This model requires an advanced reasoning component on behalf of the BA as well as the SA. In this paper we tackle the case where the BA does not give a counter offer (which involves incorporating to the model all BA's trade-offs between the various attributes) to the SA, but ranks the SA's offers instead. This ranking is then provided to the SA, in order to generate a better proposal. This process continues until a mutually acceptable contract is reached. This is more efficient in cases in which the BA is not able to extract all user requirements and preferences in a completely quantified way, while being capable of selecting, classifying or rating the contract(s) proposed.

Once the agents have determined the set of issues over which they will negotiate, the negotiation process consists of an alternate succession of N contract proposals on behalf of the SA, and subsequent rankings of them by the BA, according to its preferences and current conditions. Thus, at each round, the SA sends to the BA N contracts (i.e., N packets consisting of n-plets of values of the n contract issues), which are subsequently evaluated by the BA, and a rank vector is returned to the SA. These steps are repeated until a contract proposed by the SA is accepted by the BA, or one of the agents terminates the negotiation. We hereafter consider the case where the negotiation process is initiated by the BA who sends to the SA an initial *Request for Proposal* (*RFP*) specifying the types and nature of the contract issues and the values of all non negotiable parameters.

2.2 Negotiation Model

In this section, an efficient dynamic negotiation model is presented, based on the multi-issue value scoring system introduced in (Raiffa, 1982), for bilateral negotiations involving a set of quantitative variables. Our aim is to incorporate this framework into a multi-party, multi-issue, dynamic model. This is important since multilateral negotiations are common in the electronic marketplace. Based on the designed negotiation protocol, the proposed model is exploited by the SA to create subsequent contracts, while used by the BA to evaluate and rate the contracts offered.

It has been argued in the literature (e.g., Faratin, 1998), that Raiffa's framework is based on several implicit assumptions that, even though they may lead to good optimisation results, they are inappropriate for the needs of the e-marketplace, such as: (i) privacy of information for the negotiators is not supported, (ii) the utility function models must be disclosed, (iii) the value regions for the contract issues for both parties must be identified in advance, (iv) the only parameters that determine the utility of the contracts for the negotiators are the values of the issues under negotiation.

However, there are usually several issues, that even though their values are not under negotiation and they are not included in the contract parameters, they affect the evaluation of the values of the contract issues. Without being exhaustive, such issues may consist of: the number of competitor companies, the number of substitute or complementary products/services, the quantity of product in stock, the number of current potential buyers, the reputation/reliability of each party, the time upon which the negotiation deadline is reached, the resources availability and restrictions, etc. We will refer to these issues as *decision issues* (*DIs*). The values of the DIs may change overtime, depending on the e-marketplace conditions and on the Seller's and Buyer's state. The DIs not only affect the evaluation of the contracts, but they also have an impact on the generation of subsequent offers. It is noted here that DIs' values do not necessarily depend on the actions of the negotiating party they affect, while they may affect one or both negotiators. The values of the DIs should have a strong and direct influence on the behaviour of the negotiating agents, as they must be able to evaluate the utility of the contracts under the current conditions in the e-marketplace and act accordingly.

From the above analysis, it is clear that optimal solutions cannot be found in the e-commerce domains, as computational and communication resources usually impose non-zero negotiation duration and time-varying issues may change the conditions for both parties. Thus, we propose a dynamic model for agents' negotiation that can be exploited by strategies in order to accelerate the generation of contracts acceptable to all parties, while maximising the agent's own utility function.

The agents that represent *Sellers* will be denoted by $S=\{S_1,S_2,...\}$ and the ones that represent potential *Buyers* will be denoted by $B=\{B_1,B_2,...\}$. For the values of the DIs we will use the following notation: d_j, $j=1,...,m$. Let $U_i^a:[m_i^a,M_i^a]\to[0,1]$ express the utility that agent $a\in S\cup B$ assigns to a value of contract issue i in the range $[m_i^a,M_i^a]$ of its acceptable values. Let w_i^a be the importance of issue i for agent a. We assume the weights of all agents are normalised to add up to 1, i.e., $\sum_{i=1}^{n} w_i^a=1$. Using the above notation, the agent's a utility function for a contract $C_k=\{c_{k1},...,c_{kn}\}$ can be defined as follows: $U^a(C_k)=\sum_{i=1}^{n} w_i^a U_i^a\left(c_{ki},d_j^{t=t_k}\right)$, where $d_j^{t=t_k}$, $j=1,...,m$, is the value of decision issue d_j at the time t_k, when contract C_k is proposed. Examples of utility functions formulations (e.g. linear, polynomial, exponential, quasilinear, ...) are evaluated in (Roussaki, 2003).

In order for the utility function of any contract issue i for any negotiator to lie within the range $[0,1]$, the value c_i of issue i must lie within the range of its acceptable values. To ensure this, we introduce the notion of *value constraints*, that is expressed as follows: $m_i^a\le c_i\le M_i^a$. In case the *value constraints* hold for all contract issues, the utility function can be used to measure the satisfaction of a negotiator as far as the proposed contract is concerned. Nevertheless, often, the value constraints are not met for some contract issues, thus constituting the contract completely unacceptable, regardless of the utility level. In this case, there is not much value in using the above specified utility function to measure the satisfaction degree of this negotiator. In that sense, agents exhibit lexicographic preferences. Thus, we may introduce a *value constraint validity vector*: $VCV^a=[VCV_i^a]$, $i=1,...,n$, where $VCV_i^a\in\{0,1\}$, depending on whether the value constraint for negotiating party a is met for contract issue i (i.e., $VCV_i^a=1$) or not (i.e., $VCV_i^a=0$).

As already mentioned in *subsection 2.1*, the BA ranks the contracts proposed by the SA. For the simplest ranking function, the ranks that may be assigned to any contract proposed are boolean variables, i.e. one instance of the set $\{accept,reject\}$. In a more sophisticated approach, the ranks lie within a range $[m_r,M_r]$, where any contract rated with less than M_r is not acceptable by the BA, while, when a contract is rated with M_r, then the negotiation terminates as the proposed by the SA contract is accepted by the BA. In order to signal the case where at least one value constraint is not met for the BA for a certain contract, we introduce another parameter called *contract value constraints validity* that will be denoted by $CVCV_k^a$ for contract C_k and is given by the following equation: $CVCV_k^a=\prod_{i=1}^{n} VCV_{ki}^a$. Based on the previous analysis, in case all *value constraints* are met for contract C_k, it stands that $CVCV_k^a=1$. On the other hand, in case at least one *value constraint* is not valid for contract C_k, it stands that $CVCV_k^a=0$, and then the particular contract is definitely rejected.

In order to introduce the time parameter in our negotiation model, we represent by $P^t=\{C_1^t,...,C_N^t\}$ the vector of the $N\ge 1$ contracts proposed by the Seller Agent S to the Buyer Agent B at time t, by

$C_k^t = \{c_{k1}^t, ..., c_{kn}^t\}$ the vector of the n contract issues values proposed by S to B at time t for the k-contract of this proposal ($k = 1,...,N$), and by c_{ki}^t ($i = 1,...,n$) the value of issue i proposed by S to B at time t for the k-contract of this proposal. Let now $R^t = \{r_1^t, ..., r_N^t\}$ be the vector of ranking values that B assigns at time t to the previous contracts proposal made by S, and r_k^t ($k = 1,...,N$) be the rank that B assigns at time t to the k-contract of this proposal.

A contract package proposal is accepted by B when at least one contract is rated with M_r, while the negotiation terminates either in case the agent(s) deadline is reached or in the case where a boolean variable expressing the wish of the agents to quit the negotiation is set to true. If an agreement is finally reached, then we call the negotiation successful, while in case one of the negotiating parties quits it is called unsuccessful. In any other case, we say that the negotiation thread is active.

3. THE PROPOSED NEGOTIATION STRATEGY

Our focus is laid on the rationale of the SA, since its adopted strategy will define the outcome of the negotiation, while rather simplified assumptions regarding BA's logic are made. As already stated, a negotiation is successful, if a mutually acceptable contract is generated within reasonable time. Since an exhaustive exploration of the possible contract space may form a computationally intensive task for the SA, it should be able to infer the acceptable contract space for the BA until a predefined deadline. In our approach, SAs are provided with a mechanism enabling them to find good (near optimal) solutions in reasonable time, by means of computationally efficient algorithms. The rest of this section is structured as follows. In subsection 3.1 the negotiation problem is formally described, while in subsection 3.2 an innovative negotiation strategy is thoroughly presented.

3.1 Negotiation Problem Description

The objective of our problem is to find a contract $C_{final} = \{c_{1final}, c_{2final}, ..., c_{nfinal}\}$ that maximises the Seller's overall utility function $U^S(C_{final})$, i.e., the Seller's satisfaction stemming from the proposed contract, while the constraints on the acceptable value ranges, the utility reservation values and the negotiation deadlines for both the BA and the SA are satisfied. Thus, based on the selected protocol and the proposed model, designing a negotiation strategy can be reduced to a decision problem that can formally be stated as follows:

Given: (i) two negotiating parties: an SA that may provide a specific good (i.e. service or product) and a BA that is interested in this good's acquisition, (ii) n contract issues (index: $i = 1,...,n$) defined by the negotiators and the acceptable for the SA ranges $[m_i^S, M_i^S]$ within which their values must lie, (iii) m decision issues and their current values d_j, $j = 1,...,m$, (iv) a deadline T up to which the SA must have completed the negotiation with the BA, (v) the vector $P^{t_l} = \{C_1^{t_l}, ..., C_N^{t_l}\}$ of the N contracts $C_k^{t_l} = \{c_{k1}^{t_l}, ..., c_{kn}^{t_l}\}$ ($k = 1,...,N$) proposed by the SA to the BA during the previous round l, (vi) the vector $R^{t_l} = \{r_1^{t_l}, ..., r_N^{t_l}\}$ of the ranking values $r_k^{t_l}$ ($k = 1,...,N$) that the BA assigns to the previously made by the SA contract proposal at the negotiation round l, and (vii) the value constraint validity vector $VCV_k^B = \{VCV_{ki}^B\}$ ($i = 1,...,n$) for at least one of the contracts proposed, *find* the vector $P^{t_{l+1}} = \{C_1^{t_{l+1}}, ..., C_N^{t_{l+1}}\}$ of the N contracts $C_k^{t_{l+1}} = \{c_{k1}^{t_{l+1}}, ..., c_{kn}^{t_{l+1}}\}$ ($k = 1,...,N$) that should be proposed by the SA to the BA at the next round $l+1$, in order to eventually reach to an acceptable (near optimal) agreement between the two parties, while the SA aims to maximise its individual utility of the agreed contract under the SA's constraints, i.e., $VCV_k^S = \{VCV_{ki}^S\} = \underline{1}$ ($i = 1,...,n$), $U^S(C_k^{t_{l+1}}) \geq U_{\min Acc}^S$ and $t_l \leq T$, and subject to the existent resource and computational limitations.

In general, there may be a significant amount of computations associated with the optimal solution of the negotiation problem presented above. Exhaustive search (i.e., algorithms scanning the entire contract space) should be conducted only in case the solution space is not prohibitively large. The cost of the respective solutions is evaluated and finally, the best solution is maintained. The complexity of the negotiation problem is increased with regards to the number of the contract issues involved and the range of their acceptable values. In this respect, the design of computationally efficient algorithms that may provide good (near-optimal) solutions in reasonable time is required.

3.2 Negotiation Strategy

In this section an efficient negotiation strategy that fully exploits the potential of the designed negotiation model is described. This strategy is designed based on the following focal assumptions. First, the SA and the BA will reach to an agreement, only if a contract is found, whose contract issues values lie within the acceptable ranges for both negotiating parties, while their individual utilities are above a minimum acceptable threshold. Second, it is assumed that the values of all decision issues are invariable and equal to $\underline{d}^{t_0} = \{d_j^{t_0}\}$ for the maximum possible duration T of the negotiation procedure between the SA and the specific BA, where t_0 is the initiation time of the specific negotiation thread. Third, the duration $t_{l+1} - t_l$ of each negotiation round l is considered to be almost constant. Thus, the maximum number of rounds within which the SA is authorised to complete the negotiation with the BA is: $L = INT(T/(t_{l+1} - t_l))$.

The rest of the section is structured as follows. The first subsection provides the general concepts underlying the negotiation strategy designed for the SA, the second describes the ranking mechanism of the BA, while the last subsection presents in detail the SA's negotiation strategy.

General Negotiation Strategy Elements on the Seller Side

As already presented in the negotiation protocol analysis, we consider the case where the negotiation process is initiated by the BA who sends to the SA an *RFP* specifying the types of the contract issues and the values of all non negotiable parameters. Based on this *RFP*, the SA proposes an initial contract $C^{t_0} = \{c_1^{t_0}, ..., c_n^{t_0}\}$ to the BA at $t = t_0$, setting all contract issues at the values that maximise the Seller's utility (i.e. if $\partial\left[U^S\left(C_k, \underline{d}^{t_0}\right)\right]/\partial c_i > 0$, then the SA sets $c_i^{t_0} = M_i^S$, while in case $\partial\left[U^S\left(C_k, \underline{d}^{t_0}\right)\right]/\partial c_i < 0$, then the SA sets $c_i^{t_0} = m_i^S$). The utility of the initial contract C^{t_0} for the SA will be denoted by: $U^S\left(C^{t_0}, \underline{d}^{t_0}\right) = U_{\max}^{S,t_0}$, as $U_{\max}^{S,t_0}$ is the maximum utility that can be achieved for the Seller, given the values of the decision issues $\underline{d}^{t_0} = \{d_j^{t_0}\}$ at time $t = t_0$.

The proposed negotiation strategy is designed so that the number N of the contracts proposed by the SA to the BA at each negotiation round is equal to the number n of the contract issues, i.e. the following equation holds: $N = n$. The general idea of the proposed approach is that all contracts $C_k^{t_l}$ ($k = 1, ..., n$) of a negotiation round l are generated by the same "source" contract that will be hereafter denoted as $C_0^{t_l}$. All contracts of the same round are generated so that they present equal utilities for the Seller, given the values of the decision issues $\underline{d}^{t_0}$ at the beginning of the negotiation, i.e. $U^S\left(C_k^{t_l}, \underline{d}^{t_0}\right) = U^S\left(C_{k'}^{t_l}, \underline{d}^{t_0}\right)$, $\forall k, k' \in \{1, ..., n\}$, $\forall l = 1, ..., L$. Contract C^{t_0} is the "source" contract of the first complete negotiation round ($l = 0$), i.e. $C_0^{t_1} = C^{t_0}$.

If an agreement is not reached until round $l - 1$, then at the next round l, the SA will make a compromise (concession), reducing its utility by a certain quantity $\Theta^{t_l} = U^S\left(C_k^{t_{l-1}}, \underline{d}^{t_0}\right) - U^S\left(C_k^{t_l}, \underline{d}^{t_0}\right)$. As only the results and not the formulation of the designed negotiation strategy depend on the exact value of Θ^{t_l}, without loss of generality, we may assume that Θ^{t_l} is constant, i.e. $\Theta^{t_l} = \Theta^{t_0}$, $\forall l = 1, ..., L$. Hereafter, we consider that upon the Seller's deadline, the SA concedes up to its reservation value. Thus, the following stand: $U^S\left(C^{t_0}, \underline{d}^{t_0}\right) = U_{\max}^{S,t_0}$ and $U^S\left(C_k^{t_L}, \underline{d}^{t_0}\right) = U_{\min Acc}^S$. Using these two equations we may define quantity Θ^{t_0} as follows: $\Theta^{t_0} = \frac{U_{\max}^{S,t_0} - U_{\min Acc}^S}{L}$. This means that at each negotiation round, all contracts proposed by the SA will present Seller utility reduced by Θ^{t_0}, with regards to the contracts of the previous round.

As already mentioned, contract C^{t_0} for which it stands $U^S\left(C^{t_0}, \underline{d}^{t_0}\right) = U_{\max}^{S,t_0}$ is the "source" contract of the first complete negotiation round ($l = 0$), i.e., $C_0^{t_1} = C^{t_0}$. The core concept of the proposed SA's strategy is to propose N contracts at each negotiation round l, which yield the same utility concession Θ^{t_o} with respect to the source contract $C_0^{t_l}$. That is the utility of the contracts proposed is equal to $U^S\left(C_k^{t_l}, \underline{d}^{t_0}\right) = U^S\left(C_0^{t_l}, \underline{d}^{t_0}\right) - \Theta^{t_0}$, while $U^S\left(C_k^{t_{l-1}}, \underline{d}^{t_0}\right) = U^S\left(C_0^{t_l}, \underline{d}^{t_0}\right)$, $\forall k = 1, ..., n$. According to the previous analysis, we have the following: $U^S\left(C^{t_0}, \underline{d}^{t_0}\right) = U_{\max}^{S,t_0}$ and $U^S\left(C_k^{t_L}, \underline{d}^{t_0}\right) = U_{\min Acc}^S$. It is noted that in case an agreement between BA and SA is feasible, our approach will succeed in reaching within the negotiation thread upon an agreement due to the assumption that as its deadline approaches, the SA concedes up to its reservation value $U_{\min Acc}^S$.

As already described in the negotiation model analysis, at each negotiation round l, the SA provides the BA with a contract proposal $P^{t_l} = \{C_1^{t_l}, ..., C_n^{t_l}\}$. The BA in return, sends to the SA the ranking vector $R^{t_l} = \{r_1^{t_l}, ..., r_n^{t_l}\}$ for the respective contract package proposal along with the *value constraint validity vector* $VCV^{B,t_l} = \{VCV_i^{B,t_l}\}$, $i = 1, ..., n$, for the "source" contract $C_0^{t_l}$ of the round, where $VCV_i^{B,t_l} \in \{0,1\}$, depending on whether the value constraint of the BA is met for issue i (i.e., $VCV_i^{B,t_l} = 1$) or not (i.e., $VCV_i^{B,t_l} = 0$) for this contract. In the above approach, obviously, in case $VCV_i^{B,t_l} = 0$, i.e., the value of contract issue i set by the SA to the "source" contract $C_0^{t_l}$ does not lie within the acceptable range $\left[m_i^B, M_i^B\right]$ of the BA, then the rank of the contracts generated by $C_0^{t_l}$ will be equal to zero, as they are rejected by the BA.

The ranking mechanism of the Buyer

The strategy proposed in this paper considers the case where the BA returns to the SA an identification sign of the "*best contract*" comprised in the contract package proposal $P^{t_l} = \{C_1^{t_l},...,C_N^{t_l}\}$ in the context of each negotiation round l. In essence, the BA in such a case may only identify the contract that better satisfies his/her needs, requirements and constraints and not provide a specific rank as a measure of his/her satisfaction stemming from the proposed contracts. Therefore, the BA rationale may be quite simple, but the SA task is still quite difficult due to the limited information provided. The best contract $C_k^{t_l}$ at each negotiation round l is identified by a rank signal BC (i.e., $R^{t_l} = \{0_1^{t_l},...,BC_k^{t_l},...,0_N^{t_l}\}$), whereas in case a contract $C_k^{t_l}$ is accepted to form the final agreement between the negotiating parties the specific rank provided at the respective contract position of the ranking vector R^{t_l} is set equal to 1 (i.e., $R^{t_l} = \{0_1^{t_l},...,1_k^{t_l},...,0_N^{t_l}\}$). At this point it should be noted that in case all contracts proposed present a value constraint violation (i.e., if for $c_{ki}^{t_l}$, $i = 1,...,n$, $\forall k = 1,...,N$, it stands that $VCV_k^{B,t_l} = 0$), the ranks comprised in the ranking vector R^{t_l} returned to the SA are set equal to 0 (i.e. $r_k^{t_l} = 0$, $\forall k = 1,...,N$).

The Contract Generation Mechanism of the Seller

The basis for the proposed negotiation strategy for the Seller is the first subsection, describing the general negotiation elements on the seller's side. As already mentioned, contract C^{t_0} for which it stands $U^S\left(C^{t_0}, \underline{d}^{t_0}\right) = U_{\max}^{S,t_0}$ is the "source" contract of the first complete negotiation round ($l = 0$), i.e. $C_0^{t_1} = C^{t_0}$. With respect to this initial contract C^{t_0} two distinct cases may be identified. First, no *value constraint violation* exists and the contract C^{t_0} is ranked by the BA with a rank signal BC (i.e., $r^{t_0} = BC$). Second, *value constraint violation* occurs, in which case $r^{t_0} = 0$, and the BA provides also its *value constraint validity vector* VCV^{B,t_0}. In case the initial contract C^{t_0} presents a *value constraint violation*, the SA, as a first step, tries to acquire a contract that respects BA's value constraints. We will refer to this step as *negotiation phase I*. To this respect, until a non value constraint violating contract C^{t_l} is acquired (thus, $r^{t_l} \neq 0$), at each negotiation round $l > 1$ only one new contract is generated on the basis of the contract $C^{t_{l-1}}$ proposed at negotiation round $l-1$ (which in essence forms the source contract $C_0^{t_l}$, i.e., $C_0^{t_l} = C^{t_{l-1}}$). This generation mechanism considers that the C^{t_l} contract will in principle have all contract issues values equal to the ones of the "source" contract $C_0^{t_l}$, except from the value(s) $c_{0i}^{t_l}$ of contract issue(s) i, for which a constraint violation has occurred, ($VCV_i^{B,t_l}(C^{t_l}) = 0$). For example, in case contract issue k of the "source" contract $C_0^{t_l}$ violates the value constraints, the new contract proposal would be $C^{t_l} = \{c_{01}^{t_l},...,c_{0(k-1)}^{t_l}, c''^{t_l}_{0k}, c_{0(k+1)}^{t_l},...,c_{0n}^{t_l}\}$. The value(s) of contract issue(s) k, $c''^{t_l}_{0k}$, are selected so that the utility of contract C^{t_l} for the SA is equal to: $U^S\left(C^{t_l}, \underline{d}^{t_0}\right) = U^S\left(C_0^{t_l}, \underline{d}^{t_0}\right) - \Theta^{t_0}$, where $U^S\left(C^{t_{l-1}}, \underline{d}^{t_0}\right) = U^S\left(C_0^{t_l}, \underline{d}^{t_0}\right)$. Thus, the main concept of the proposed strategy remains the same. In order to reach a non violating contract within a limited number of negotiation rounds, it is assumed that the concession degree Θ^{t_0} is shared equally amongst the contract issues whose value is not acceptable to the BA. The exact values of contract issues are determined in accordance with the following formulae:

$$c''^{t_l}_{0i} : U^S\left(c_{0i}^{t_l}, \underline{d}^{t_0}\right) - U^S\left(c''^{t_l}_{0i}, \underline{d}^{t_0}\right) = \frac{1}{\sum_{k=1}^{n} \overline{VCV_k^{B,t_l}}} \cdot \frac{\Theta^{t_0}}{w_i^S} \quad (1)$$

This process continues till a non value constraint violating contract C^{t_l} is acquired (i.e., $r^{t_l} \neq 0$), in which case the Seller's strategy is modified in order to acquire a mutually acceptable contract within reasonable time. Specifically, this contract becomes the "source" contract for the next negotiation round, during which the SA provides the BA with a contract package proposal comprising $N = n$ contracts. The negotiation round upon which the first negotiation phase ends (hence, the strategy of the Seller is modified) will be hereafter denoted as nr_{fs}. It is noted that in any negotiation round $l > nr_{fs}$, due to the specific approach adopted (i.e., sequential utility concession by quantity Θ^{t_0}), no contract proposed may present any value constraint violation.

Moving now to *negotiation phase II*, concerning the generation process of the "source" contract $C_0^{t_l}$ of a negotiation round $l > nr_{fs}$, the current version of this study considers the simplest possible assumption, that is the "*best contract*" proposed to the BA at the negotiation round $l-1$, as determined by the ranking vector R^{t_l} returned to the SA, forms the "source" contract for negotiation round l. Alternatively, for the specification of the source contract $C_0^{t_l}$, the SA could employ exploration techniques.

Up to this point, we have not yet presented the way the $N = n$ contracts of any negotiation round $l > nr_{fs}$ are generated by the round's "source" contract $C_0^{t_l}$. The contract generation mechanism, is based on the idea that in any $C_k^{t_{l+1}}$ the SA at each negotiation round $l+1$ will in principle concede mostly with respect to the contract issue which have been on the previous negotiation round l preferred by the BA, while through the modification of one additional contract issue up to a certain amount the SA infers the direction towards which should move in order to reach to an agreement with the BA.

Considering the first negotiation round l of *negotiation phase II* (i.e., $l = nr_{fs} + 1$), the SA proposes n contracts which will in principle have all contract issues values equal to the ones of the "source" contract $C_0^{t_l}$, except from the value $c_{kk}^{t_l}$ of contract issue $i = k$, i.e. $C_k^{t_l} = \{c_{01}^{t_l}, \ldots, c_{0(k-1)}^{t_l}, c_{kk}^{t_l}, c_{0(k+1)}^{t_l}, \ldots, c_{0n}^{t_l}\}$. The value $c_{kk}^{t_l}$ is selected so that the utility of contract $C_k^{t_l}$ for the SA is equal to: $U^S\left(C_k^{t_l}, \underline{d}^{t_0}\right) = U^S\left(C_0^{t_l}, \underline{d}^{t_0}\right) - \Theta^{t_0}$. This way, the SA explores what is the impact of the value concession of each one of the contract issues. Following the presented approach, one may observe that for the "*best contract*" $C_k^{t_l}$ indicated by the BA, the same SA utility reduction Θ^{t_0} due to adjustments on the value $c_{kk}^{t_l}$ of contract issue $i = k$, is valued higher by the BA. On the other hand, in case any contract $C_k^{t_l}$ is not indicated as the "*best contract*" on negotiation round l (where all Seller utility reduction Θ^{t_0} is due to adjustments on the value c_{kk}^{t} of contract issue $i = k$), this indicates that contract issue $i = k$ is not very important for the BA. In accordance with the proposed approach, in the context of the next negotiation round, the SA exploits the "*best contract*", as indicated by the BA in the R^{t_l} vector, which forms the "source" contract for the next round. Thus, in case this contract is $C_k^{t_l}$ (i.e., $C_k^{t_l} = C_0^{t_{l+1}}$), it does "worth" it for the SA to propose during the next negotiation round $l+1$ a contract package proposal, whose main characteristic is that a high percentage of the total Seller utility reduction Θ^{t_0} is due to adjustments on the value $c_{kk}^{t_l} = c_{0k}^{t_{l+1}}$ of contract issue $i = k$.

We hereafter introduce with respect to each contract issue i a variable called *utility concession degree*, denoted as $ucd(i)$, representing the percentage of the total Seller utility reduction Θ^{t_0} due to the adjustment of the contract issue i value. It holds $ucd(i) \in [0,1]$. The n contracts constituting the contract package proposal considered in negotiation round $l+1$ may be generated as follows. The first contract is created by modifying only the value $c_{0k}^{t_{l+1}}$ of k contract issue, whose adjustment on the previous negotiation round l was preferred by the BA. Thus, the Seller's utility reduction Θ^{t_0} is introduced only by adjusting $c_{0k}^{t_{l+1}}$ in the source contract. The value $c_{kk}^{t_{l+1}}$ may be calculated by means of the following equation $c_{kk}^{t_{l+1}}$: $U^S\left(c_{kk}^{t_l}, \underline{d}^{t_0}\right) - U^S\left(c_{kk}^{t_{l+1}}, \underline{d}^{t_0}\right) = ucd(k) \cdot \frac{\Theta^{t_0}}{w_k^S}$, where $ucd(k) = 1$. The rest $n-1$ contracts are generated by modifying at each contract the value $c_{0j}^{t_{l+1}}$ of one more issue j ($j \neq k$) in the source contract, up to a certain degree $ucd(j)$, while the utility concession degree $ucd(k)$ of the k contract issue is properly adjusted, so that $ucd(j) + ucd(k) = 1$. This way, the impact of the combined Seller's utility reduction with respect to both modified contract issues is explored. The contracts which are specified in accordance with this concept will be hereafter called "exploration" contracts. The values $c_{kk}^{t_{l+1}}$ and $c_{jj}^{t_{l+1}}$ of contract issues k and j respectively may be acquired by means of equation (1). It stands that $\sum_{i=j,k} w_i^S \cdot [U^S(c_{ii}^{t_l}, \underline{d}^{t_0}) - U^S(c_{ii}^{t_{l+1}}, \underline{d}^{t_0})] = \Theta^{t_0}$, which indicates that the Seller's utility of the n contracts of negotiation round $l+1$ is less than the Seller's utility of the negotiation round l by the quantity Θ^{t_0}, which is fully consistent with the presented approach. In the experiments conducted (Roussaki, 2003), for the generation of the $n-1$ "exploration" contracts, $ucd(k)$ is set equal to 0.7, while $ucd(j)$ equals 0.3, as it is believed by the authors that 30% is adequate for exploration purposes.

In case the BA ranks higher the introduction of the modification of contract issue j with respect to the value adjustment of contract issue k, as a next step, the respective utility concession degrees $ucd(j)$ and $ucd(k)$ are modified so that the relative preference of the BA for contract issue j is introduced in the generation process of the next negotiation round $l+2$. Specifically, considering the next negotiation round contract generation, the utility concession degree of contract issue j is increased, while the utility concession degree of contract issue k is decreased as we consider that the SA should concede mostly with respect to contract issue j. Thus, $ucd(j)$ is set equal to 0.7, while the rest 0.3 portion of the utility concession quantity Θ^{t_0} is at each contract assigned to each one of the contract issues m in a manner similar to the "*exploration*" policy introduced above. Following the presented approach, it may easily be deduced that at each negotiation round l, the contracts generated from the source contract $C_0^{t_l}$ modify the values of two contract issues, where the contract issue preferred by the BA during the previous negotiation round $(l-1)$ is attributed with utility concession degree that is equal to 0.7, while a 0.3 percentage is assigned to each one of the contract issues at each negotiation round. In order to make the proposed contract generation mechanism more comprehensive to the reader, in *Table 1* we present

Neg. Round	$l = nr_{fs} + 1$	$l+1$	$l+2$
Contracts Proposed	$(c'^{l}_{1}, c^{l}_{2}, c^{l}_{3})$, $ucd(1)=1$	$(c'^{l+1}_{1}, c'^{l+1}_{2}, c^{l+1}_{3})$, $ucd(2)=0.7$, $ucd(1)=0.3$	$(c'^{l+2}_{1}, c^{l+2}_{2}, c'^{l+2}_{3})$, $ucd(3)=0.7$, $ucd(1)=0.3$
	$(c^{l}_{1}, c'^{l}_{2}, c^{l}_{3})$, $ucd(2)=1$	$(c^{l+1}_{1}, c'^{l+1}_{2}, c^{l+1}_{3})$, $ucd(2)=1$	$(c^{l+2}_{1}, c'^{l+2}_{2}, c'^{l+2}_{3})$, $ucd(3)=0.7$, $ucd(2)=0.3$
	$(c^{l}_{1}, c^{l}_{2}, c'^{l}_{3})$, $ucd(3)=1$	$(c^{l+1}_{1}, c'^{l+1}_{2}, c'^{l+1}_{3})$, $ucd(2)=0.7$, $ucd(3)=0.3$	$(c^{l+2}_{1}, c^{l+2}_{2}, c'^{l+2}_{3})$, $ucd(3)=1$
Source Contract	$(c^{l}_{1}, c^{l}_{2}, c^{l}_{3})$	$(c^{l}_{1}, c'^{l}_{2}, c^{l}_{3})$, $ucd(2)=1$	$(c^{l+1}_{1}, c'^{l+1}_{2}, c'^{l+1}_{3})$, $ucd(2)=0.7$, $ucd(3)=0.3$

Table 1: An example of the proposed negotiation strategy.

the logic underlying by means of a simple example, considering the case of three contract issues.

According to the proposed approach, in case the resulting value $c^{t_{l+1}}_{kk}$ of a contract issue k in contract $C^{t_{l+1}}_{k}$ ends up to lie outside the acceptable range of the SA, then if $c^{t_l}_{kk} < m^S_k$ (or $c^{t_l}_{kk} > M^S_k$), the value selected is $c^{t_l}_{kk} = m^S_k$ (or $c^{t_l}_{kk} = M^S_k$), while the remaining utility is equally "distributed" among the rest of the contract issues that have not yet reached their limit values.

4. CONCLUSIONS

This paper presented a multiparty, multi-issue, dynamic negotiation model and an effective strategy, to be exploited by mobile intelligent agents in an e-commerce environment, in case the disclosure of information is not acceptable, possible, or desired. Additionally, the efficiency of the proposed framework is due to the fact that the Buyer agent adopts a flexible and light reasoning component, which does not necessitate the explicit statement of all preferences and requirements on behalf of the Buyer in a completely quantified way. A ranking mechanism replaces the counter-offer complicated scheme, while potential decision issues are considered. Thus, it supports an evaluation of the contracts proposed, based not only on the values of the issues under negotiation, but also on the e-marketplace conditions and the negotiators' state. The proposed negotiation strategy is adequate for the simple ranking function. It demonstrates exceptional efficiency in cases where the buyer is not able to provide all his/her requirements and preferences in a completely quantified way, while being capable of selecting the contract that best satisfies his/her needs. Besides its inherent computational and communication advantages, its efficiency is due to the fact that an agreement between Buyer and Seller is reached in any situation it is feasible, before the predefined deadline expires.

The negotiation framework designed has been adopted by self-interested autonomous agents and has performed well on the generation of subsequent offers and the ranking of the contracts proposed, always converging to a mutually acceptable contract, if any. Initial results indicate that the designed framework produces near optimal results, in case the number of the negotiation issues is quite high. Future plans involve its extensive empirical evaluation against existent models and strategies and against the optimal solution of the negotiation problem.

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