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Agent-supported Negotiations in the E-marketplace *

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Abstract

A key requirement for customer-oriented e-marketplaces is the personalization and customization of products and services, as well as personalized fulfilment. Negotiations are at the core of these processes. In this paper an e-marketplace, eAgora, is discussed. It allows buyers and sellers to engage in multi-issue negotiations. eAgora implements several protocols based on a negotiation phase model constructed for this system. Its services include a software agent that generates and critiques offers. Based on a small scale usability testing with participants, who conducted negotiations with and without the agent, the agent's services were found useful. The users also requested additional agent's services including enhanced offer critique and partial negotiation automation.

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1. Introduction

Since 2001 retail e-commerce sales in the USA have been increasing by 26-27% on a quarterly basis and in the second quarter of 2003 had approached the 13 billion dollars mark (Census 2003). Although this amount represents only 1.5% of the total sales, the increase is over 500% higher than the total retail sales increase in the USA for the same time period. This is an indication of the growing significance of e-commerce and, in particular, consumer-oriented e-markets.

A key requirement for consumer-oriented e-marketplaces is the personalization and customization of products and services, as well as personalized fulfilment. These functions differentiate e-markets from traditional markets, since the former allow for better matching of buyers' and sellers' requirements. Auctions and negotiations are at the core of the personalization and customization processes. On-line auctions are used when attributes are well-defined and known prior to the initiation of the transaction process. Auctions are popular, because they are highly efficient and they reduce transaction costs. Negotiations are used in situations when the product's and/or transaction's attributes need to be discussed, i.e., when the parties cannot define all relevant product or service attributes *a priori*.

Negotiation has been a research topic of anthropologists, psychologists, sociologists, economists and operation researchers. Anthropologists studied negotiations in various cultural settings and proposed their phase models (Gulliver 1979). Psychologists and sociologists have been concerned with the negotiators' behaviour, impact of their individual characteristics and biases on the negotiation process and outcomes (Bazerman, Curhan et al. 2000). Economists' contribution has been mainly in the construction of normative models (Young 1975) and their falsification (Roth 1995). Operations researchers constructed normative and prescriptive models to help analysts provide advice to the negotiators (Young 1991; Raiffa, Richardson et al. 2003).

Research on negotiation support had started at the beginning of the 80's (Kersten 1987; Jelassi and Foroughi 1989). Until recently, there have been few successful implementations of negotiation support systems (NSSs). The successful NSSs were used by intermediaries rather than by negotiators, such as in trans-boundary air pollution and in deep sea negotiations (Sebenius 1984; Amman 1999), as well as in education regarding group decision support systems and electronic bargaining tables (Kersten 1985; Rangaswamy and Shell 1997).

The limited use of the early NSSs was due to: (1) limitations of information and communication technologies (ICTs); (2) limited computer literacy of managers, who therefore, delegated the system usage to analysts; (3) complexity of the constructed models, often based on strong rationality principles, that required significant amount of users' input; and (4) insufficient consideration of psychological and sociological conditioning of negotiations.

New ICTs, including Internet, software architectures, and software development technologies made rapid development of systems for millions of users possible. They also exposed people to information systems and their practical use for shopping, communication, information retrieval and entertainment. These developments led to two new streams of theoretical and applied research: (1) behavioural research on the use of communication technologies (mainly email) in negotiations (Purdy and Neye 2000; Thompson and Nadler 2002); and (2) design of easy-to-use e-negotiation systems (ENSs).

ENS is software that employs Internet technologies for use in preparing and conducting negotiations. It is mainly deployed on the web to facilitate and organize negotiations, and to support and aid

negotiators (Bichler, Kersten et al. 2003). ENS design and development efforts were initiated by computer scientists, who espoused the engineering approach to negotiations that focused on efficiently automating negotiation processes, rather than correctness of embedded preference elicitation and utility construction models (Guttman and Maes 1998). Within this stream innovative approaches based on collaborative filtering to preference modelling have been proposed (Balabanovic and Shoham 1997) and implemented (e.g., by Amazon.com).

Initially, e-market development efforts concentrated on fixed-price and single-issue auction systems (Kumar and Feldman 1998; Bichler 2000). Increased sophistication of e-market systems and maturity of e-commerce led to the recognition of negotiation as an effective mechanism for business transactions (Kersten, Noronha et al. 2000; Schoop and Quix 2001; Ströbel 2003). Software firms now provide negotiation components in procurement and supply chain management systems (e.g., Oracle, SAP and PeopleSoft). Other developers introduced software agents to automate negotiation processes (Maes, Guttman et al. 1999; Lomuscio, Wooldridge et al. 2000; Jennings, Faratin et al. 2001); such agents have been successfully used for bidding in well defined domains (Jennings, Faratin et al. 2000).

E-markets that provide buyers and sellers with auction mechanisms are well known and widely used today (e.g., eBay, YahooActions and AmazonAuctions). E-markets that provide individual buyers and sellers with bargaining and negotiation mechanisms have also been proposed. Kasbah and Tete-a-Tete are two experimental markets that allow customers to use software agents to negotiate on their behalf (Guttman, Moukas et al. 1998; Maes, Guttman et al. 1999). However, these two systems cannot handle negotiations that evolve in time with new issues being added or dropped. Other approaches include: Oliver's application of genetic algorithms in simulated automated negotiations where negotiation agents learned strategies (Oliver 1997); and Ito and Shintani's design of negotiations among multiple software agents (Ito and Toramatsu 1997). In the latter work, the agents evaluated counter-proposals in terms of their impact on their decision trees. In the case of a significant impact the users were asked to re-evaluate their decisions (Ito and Toramatsu 1997).

Delegation of the negotiation activities to agents imposes the requirement that the negotiation problem be well-defined. Therefore, in our view automated negotiations have limited potential in real-life business negotiations. Their use could be more beneficial in technical applications (e.g. involving database servers, printers and power generators). For example, a multi-agent system "Challenger" is proposed for distributing computational load among multiple machines (Chavez, Moukas et al. 1997). However, we feel that agents could provide valuable services as part of negotiation support. To this date application of agents for negotiation support has been limited. One such agent-based system, Aspire is an ENS that combines decision support with software agents providing advice to negotiators (Kersten and Lo 2003). Its limitation is in the lack of connectivity to an e-marketplace and restricted functionality on the part of the software agent; the agent is unable to generate offers or critique offers.

In this paper, we propose eAgora, an ENS for multi-issue negotiations between buyers and sellers with an integrated software agent. The agent's main role is to generate and critique offers and counter-offers. The focus of this paper is on the design and implementation issues of agent-supported negotiations in e-marketplace and the agent's interactions with buyers and sellers. Section 2 discusses eAgora's negotiation processes using a phase model of negotiation for negotiation activities and protocols. Section 3 examines the agent model for offer generation and critiquing. Section 4 describes the system architecture and design. An example of the use of eAgora is given in Section 5. In Section 6 we discuss the preliminary usability testing of eAgora as well as directions for future research.

2. Negotiation process, support and services

2.1 Phase model of negotiations

The use of support systems and software agents in negotiations requires that a *process model* and a *protocol* be constructed (Kim and Segev 2003). The process model describes the sequence of the negotiation activities and phases. The protocol is a formal model, often represented by a set of rules. It governs software processing and communication tasks, and imposes restrictions on activities through the specification of permissible inputs (Jennings, Faratin et al. 2001).

Several negotiation phase models have been discussed in the negotiation literature, ranging from a two-phase model (Ghee-Soon Lim and Murnigham 1994), to three (Holmes 1992), to an eight-phase model (Gulliver 1979). From the perspective of constructing an ENS, a more detailed model is preferable because it allows for a better (finer) determination of activities and their processing requirements. From the ENS users' perspective, a phase model is also required because it allows the negotiators to follow a methodologically sound approach (Lewicki, Saunders et al. 1999).

Behavioural research on negotiations so far has not included the processes in which support systems and software agents are involved as active participants. Therefore, we need to adapt a behavioural phase-model to reflect the requirements imposed by an ENS. In the eAgora system we have adapted a model proposed by Kersten (1997), which is based on Gulliver's eight-phase model (1979). This model is modified to allow for a wider range of negotiated decisions than the eight-phase model, including those which use ENSs. The model comprises the following five phases:

1. *Search for arena and selection of the communication mode*. The participants select and agree on the location where the decision process may occur. Selection of the communication mode includes choice of the synchronous or asynchronous exchange of information, discussions and negotiation on partial or complete offers, and joint use of experts, mediators and facilitators. While this phase is important to ENSs in general, in our situation it is ignored because we consider only one arena and one communication mode (via eAgora).

2. *Agenda setting.* Negotiators discuss and agree on the terminology and the issues to be decided upon. The activities of this phase set the stage for subsequent phases. They involve joint construction of the initial problem representation (e.g., specification of the decision attributes and the bargaining ranges). The result of this phase includes the initial personalization and/or customization of the negotiation subject (i.e., product or service) in accordance with the needs of the negotiators.

3. *Exploring the field*. This phase involves further problem specification and its analysis. In negotiation the parties try to establish limits to the issues, formulate their best alternatives to the negotiating agreement (BATNA), and establish reservation prices and aspiration levels for specific objectives. Support systems have been used in this phase for the purpose of simulation and analysis of the implications of decision alternatives.

4. *Narrowing the differences and search for agreement.* Exchange of offers, arguments, threats and other information are the key activities in this phase. These exchanges allow the parties (and/or software) to learn of the limitations of the opponent and identify the key issues and critical areas of disagreement. During this phase the parties realize the potential for a compromise and can assess its main features and implications. The analysis of a negotiation may focus on the selection and verification of strategies, the determination of concessions and

revision of aspiration levels, and on the restriction of efficient solutions to those which may be acceptable to the parties. In a successful negotiation, this phase ends with an agreement. Unsuccessful negotiations lead to the termination of the process, which may also take place in any of the previous phases.

5. *Agreement assessment and fulfilment.* At this stage the negotiators have already agreed on a compromise. They may evaluate it and consider possible improvements. They may also discuss additional issues which, however, have no impact on the achieved compromise. For example, the seller after agreeing on the product specification and price may give the buyer several delivery, insurance or additional warranty options.

Negotiations rarely proceed in a linear fashion. While the negotiation methodology suggests that the parties should not bypass or enter a phase before completing the previous phase, the parties may in reality need to return to any of the previous phases. They could do this if the information they obtained during the process requires a revision of their assumptions and specifications. For example, they may suggest additional communication channels and propose new issues to be negotiated. These changes may require the revision of their reservation levels and of their preferences. This evolutionary nature of the process is one of the key differences between negotiations and auctions. The latter require that the communication channel and the set of issues should be defined a priori.

2.2 Negotiation activities

This section describes the negotiation related activities supported by the ENS. Activities that involve only people may be ill-defined and initially incomplete. In order to determine a negotiation protocol we need to know not only the permissible actions and the required input and output, but also their sequence. For example, offer construction activity precedes offer submission; offer acceptance precedes analysis of the agreement efficiency. This activity sequencing can be derived from the negotiation phase model.

In defining the set of permissible activities, the roles that the negotiators play are taken into account. Since eAgora focuses on e-commerce negotiations, it explicitly supports two roles: the buyer and the seller. Figure 1 depicts the four phases implemented in eAgora and the activities undertaken in each phase.

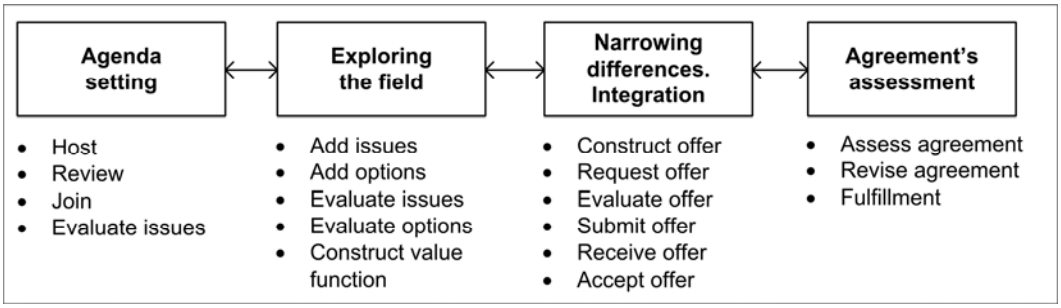

Figure 1 eAgora negotiation phase model and key activities

Phase 1: Agenda setting. The negotiation is initiated by either a buyer or a seller; the person who initiates the process is referred to as the negotiation host (*buyer_host*, *seller_host*). The activity

buyer_host (*seller_host*) requires the host to provide: (1) name of the host and her/his role; (2) product name and its short description; (3) selected product attributes (i.e., the negotiated issues) and their short descriptions; and (4) initial attribute values (i.e., issue options).

A negotiation that is set-up by a buyer (seller) can be joined by a seller (buyer). The *join_as_seller* activity involves: (1) selection of one or more buyers; and (2) review of the issues and options defined by each buyer.

Phase 2. Exploring the field. The seller who joins a negotiation may decide to add one or more new issues (*add_issue*). In this case s/he has to provide one or more options (*add_option*) for each added issue. The activity of adding a new issue and its options may lead the negotiation counterpart to suggest another issue along with the options. If the seller adds new issues and options, then the *buyer_host* can either accept or reject them. Rejection of an issue may be accepted by the person who proposed it or it may result in the termination of the negotiation (*terminate*) by that party.

Once the sets of issues and options have been tentatively accepted, the buyer and the seller assess the subjective importance of the issues and options.

Phase 3. Narrowing the differences and search for integration. The key activities in this phase involve the formulation, submission and evaluation of offers and counter-offers. The *construct_offer* activity involves: (1) selection of issues; (2) selection of options for these issues; (3) assessment of the potential offer; and (4) rejection of the offer considered for submission. If the offer is rejected, then a new offer can be constructed.

An offer that has been approved by the negotiator is submitted for consideration by her/his counter-part. The *submit_offer* activity may be a very simple "send/submit" action. It may also involve formulation of supporting arguments and reasons as to why the previous offer (if any) has been rejected.

The submitted offer is evaluated by its recipient who may accept it (*accept_offer*), reject and propose a counter-offer (this leads to *construct_offer* activity) or reject the offer and terminate the negotiation (*terminate*). If the offer is accepted, the negotiators move to Phase 4.

During this phase the negotiators may introduce new issues (this requires adding options for these issues) and/or add new options to the existing issues. The addition of new issues/options may lead -as in phase 2- to the termination of the negotiation.

Phase 4. Agreement assessment. The achieved agreement may be inefficient, i.e. there may be other alternatives that are more preferable for one side and not worse for the other, or are more preferable for both sides. The efficiency assessment is easy to conduct if both negotiators formulated their utility or value functions. In this case, the agreement's utilities (values) are compared with utilities of the feasible offers and the agreement's efficiency is determined.

If the agreement is inefficient, several efficient solutions that dominate the agreement are selected. This allows the negotiators to assess the agreement (*assess_agreement*) and revise it (*revise_agreement*) in order to achieve a better settlement. At present, eAgora does not provide users with efficiency assessments because this implies that both sides' utilities are revealed to each other, an aspect that can be uncomfortable for some negotiators. However, if both sides request such assessment, the agent will perform the efficiency analysis and generate efficient solutions.

2.3 Protocols

The purpose of the different negotiation phases is to provide the participants with a framework and guidance for activities conducted in each phase. The importance of preparation (phases 1 and 2) and the assessment of an agreement are often not appreciated by the novice negotiators.

The consideration of the phases helps to specify negotiation activities undertaken and the relationships among these activities. The activities are analyzed from the point of view of the required input and the generated output. This analysis leads to:

1. The specification of detailed actions and low-level processes which comprise an activity; and

2. The assignment of these actions and processes to the negotiators and software.

Protocol design involves the specification of roles, actions and relationships among them. Often several protocols need to be designed; a different protocol may be required for the negotiation hosted by a buyer (*buyer_host*) and a different one for *seller_host*. Part of the protocol and its specific actions designed for *buyer_host* are presented in Figure 2.

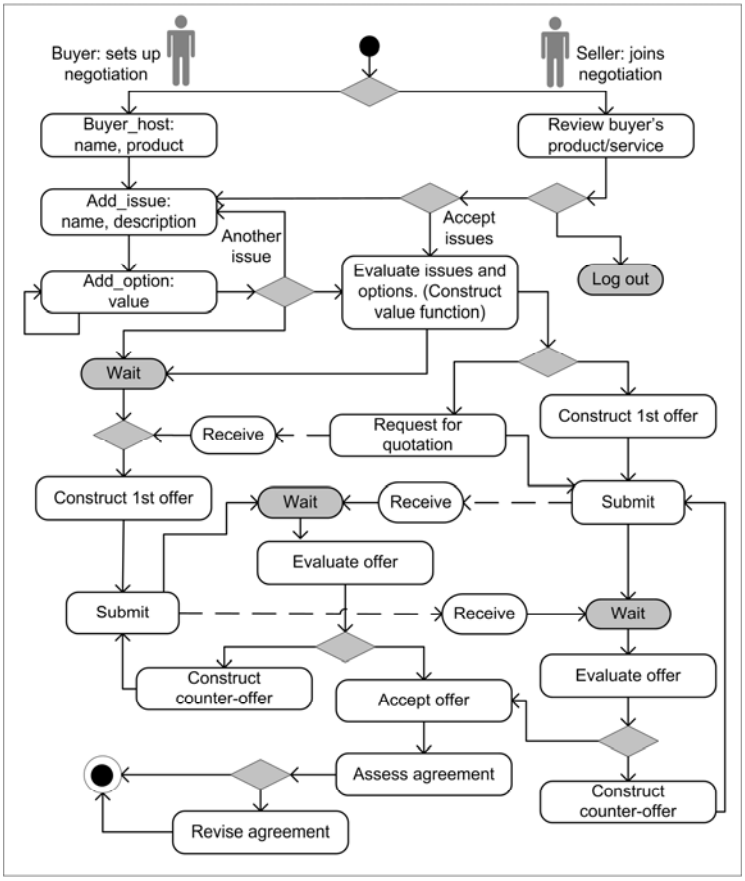

Figure 2. An example of the eAgora protocol

3. Models

The design of an ENS can be expanded with consideration of the models and ideas proposed in closely related fields, including intelligent agents for automated negotiations and decision support. The fundamental problem of employing agents in the negotiation context is the conflict between the autonomous character of agents and the ill-structured nature of real-life negotiations. While abandoning the notion of "ENS as an agent", we find it potentially useful to consider the use of embedded agents to support ENS users. In such a setup, agents will have well-defined roles within the context, which is specified by the ENS protocol. The purpose of an agent is to act as a proactive assistant to the users in the decision-making process, which at times can be difficult for novice negotiators dealing with multiple issues (Bazerman, Curhan et al. 2000).

The agent implemented in eAgora has three main objectives:

1. The identification of alternative offers that may be attractive for the user;
2. The critique of an offer that the user is considering to submit; and
3. The critique of an offer that the user receives from his/her opponent.

Offer generation by an agent in ENS context is different from that of an automated negotiation, because the agent will generate a set of different candidate offers for human negotiator to choose from. However, in automated negotiation, the agent relies solely on the preference models of the negotiators, which may only be tentative or partially articulated.

Critiquing is an important activity that could be delegated to an agent as well (Vahidov and Elrod 1999). The purpose of critiquing is to make sure the user does not make mistakes, e.g. making very large concessions. The origins of using critiquing capabilities in agents comes form the field of critiquing expert systems (Silverman 1992). The idea is that such system will not only receive description of a problem as an input, but also the proposed solution and output critique of the solution in terms of actual and potential errors. Critiquing agents "watch over the shoulder" of human users and intervene when they sense an error.

3.1 Concession-making

Single-issue transactions may be efficiently handled with auctions, while transactions that involve multiple issues and the specification of some of these issues in the process of interactions entail negotiations. During negotiations the parties construct offers, assess counter-offers and make concessions. These concessions relate to generating new offers with multiple issues.

The agent generates five alternative offers by: (1) construction of a value function in accordance with most recent preferences of the user; (2) calculating the concession level in accordance with the most recently adopted strategy; and 3) calculating actual suggested candidate offers in accordance with (1) and (2).

The overall attractiveness (value) of an offer may be assessed using a measure. In eAgora, we used a simple linear value function of the form:

$$v(\mathbf{a}_l) = \Sigma\, w_i\, v_{ij}(a_{ijl}),\ (i = 1, .., n),$$

where: $\boldsymbol{a}_l$ is a feasible alternative ($\boldsymbol{a}_l \in \mathcal{A}$, $\mathcal{A}$ – the feasible set), a_{ijl} is the j-th value of the attribute i in alternative l, w_i is the weight assigned to the i-th attribute, and $v_{ij}(a_{ijl})$ is the rating of the attribute i with value equal to a_{ijl}. Parameters w_i and $v_{ij}(a_{ij})$, ($j = 1, \ldots, m_i$; $i = 1, .., n$), are determined using the Swing method (Belton and Steward 2001).

In negotiations, the concession that negotiators are willing to make and/or accept influence their offer-making. The concession can be expressed in terms of the change (drop) in the value Δv_t ($\Delta v_t = v(\boldsymbol{a}_t) - v(\boldsymbol{a}_{t-1})$; $\boldsymbol{a}_t$, $\boldsymbol{a}_{t-1}$ – offer made in time t, t-1, respectively). As a numerical value of a concession may be meaningless for the negotiator, we used fuzzy sets to describe concession as "very small", "small", "medium", etc. These fuzzy sets represent the level of concession of which a negotiator is willing to decrease her value in order to reach an agreement.

At any point in the negotiation, the level of a concession typically depends on the strategy that the negotiator pursues, her reservation levels, BATNA and concessions made by both negotiators in the past (Raiffa, Richardson et al. 2003). In eAgora, we used a simpler formula: a concession is determined by the negotiation strategy and the opponent's previous concession measured by the change in the negotiator's value function:

$$S \wedge M \rightarrow CON,$$

where: S is the chosen strategy, and M is the opponent's move measured by the change in her or his value. Users may select any one of the four different strategies from the most to the least aggressive: competitive, collaborative, compromising and accommodating. For example, an aggressive negotiator, who is concerned mainly with substantial results and is willing to walk away from talks if the conditions are unsuitable, is likely to direct the agent to adopt a competitive strategy that focuses mostly on small concessions. This is unlike an accommodating strategy that concentrates more on larger concessions for negotiators who may sacrifice gains in order to achieve an agreement.

The concession sets an upper boundary for a drop in the negotiator's value as a result of making an offer. We used fuzzy rules of the following form in order to determine concession:

If *Strategy* is S_i and *Opponent_concession* is A_j then *Concession is* A_k

where S_i is the concrete strategy selected by the user (e.g. "competitive", "collaborative"); A_j refers to fuzzy-defined concession level made by the opponent; and A_k is the proposed concession level. An example of such a rule is:

If Strategy is competitive and Opponent_concession is medium
then Concession is small.

The resulting value of concession sets an upper limit for the drop in value function. In the second phase, a heuristic optimization method is used to derive alternative compositions that are close to the concession level derived as above. The algorithm generates five top offers that minimize the distance between the drop in the value and the concession level, but keep the former a smaller number. More formally, we search for the composition X that minimizes the distance:

$$(CON - \Delta V) \rightarrow min$$
subject to: $CON \geq \Delta V$.

Typically some issues have discrete values (e.g. delivery, warranty, return options). This demands a combinatorial type of search. In a vast majority of cases, the drop in value (ΔV) may not be strictly equal to the concession level, but may be smaller. As the preference model implemented in eAgora is linear and does not lead to local minima, an iterative improvement hill-climbing-like algorithm for the search is used (Han and Kamber 2001). Since the preference model is only an approximation of the user's true preferences, the five top alternatives are presented to the user rather than the best alternative. This also may provide the negotiator with a better idea of what good or satisficing counter-offers are like.

3.2 Offer critique

Critiquing systems were designed as an advanced means of human-machine interaction to provide their users with verbal feedback on the contemplated alternative actions (Vahidov and Elrod 1999). These systems have been proposed for use for prevention of human error as well as decision support. For example, Silverman (1992) proposed two critiquing agents each specializing in highlighting positive or negative aspects of the contemplated solution. He distinguished between different types of critique related to decision maker's objectives, preferences and soft constraints, as well as emanating from the reaction to the opponent agent's critique (counter-critique).

The "black-box" view of a critiquing system includes two types of inputs: problem description and the proposed solution. The output is a critique related to the adequateness of the given trial solution to the situation at hand. Internally, a critiquing system often has at its core the "difference analyzer", which is the engine assessing the deviation of the given solution from the region of acceptable and promising solutions (Vahidov and Elrod 1999).

We have included the capability of critiquing of offers and assessment of counter-offers as part of the eAgora agent. This critique is based on the user preferences and its purpose is to prevent the user from making major mistakes, e.g., making an offer that violates his/her reservation levels. The critiquing component C acts as a trigger. It is implemented in the form of if-then rules and has the following general form:

$$C : S \wedge V \wedge CO \wedge M \rightarrow CM,$$

where: CM is critique messages, S is the user's strategy, V is user's preferences (value), CO is the contemplated offer, and M is the last opponent's concession. In essence, S, V, and M are the "problem description", while CO is the proposed solution. Concrete rules may include a part or all of the above types of antecedents. For example, the rule for critiquing could be coded as:

> If *Strategy* is *Competitive* and *Opponent_concession* is *small* and *Contemplated_offer* is *large* then *Critique* is *Concession_too_large* ("*You are making an offer that is too generous*.")

The antecedent parts of the above rules implement the "difference analyzer" and act as triggers for generating critique, i.e. when all of the conditions are satisfied, the message is provided to the negotiator. This sort of warning may prevent negotiators from making offers that may violate their reservation levels and possibly end up with unfavourable deals. However, if no conditions in any of the rules are met, the critique is not generated

3.3 Offer generation

This subsection describes how offer generation and critique are incorporated into offer construction process shown in Figure 3. Once the negotiator receives an offer s/he must decide whether to accept it,

terminate the negotiation or make a counteroffer. This requires the offer assessment, which in eAgora is aided by the agent that proactively examines the opponent's offer in light of the negotiators' preferences.

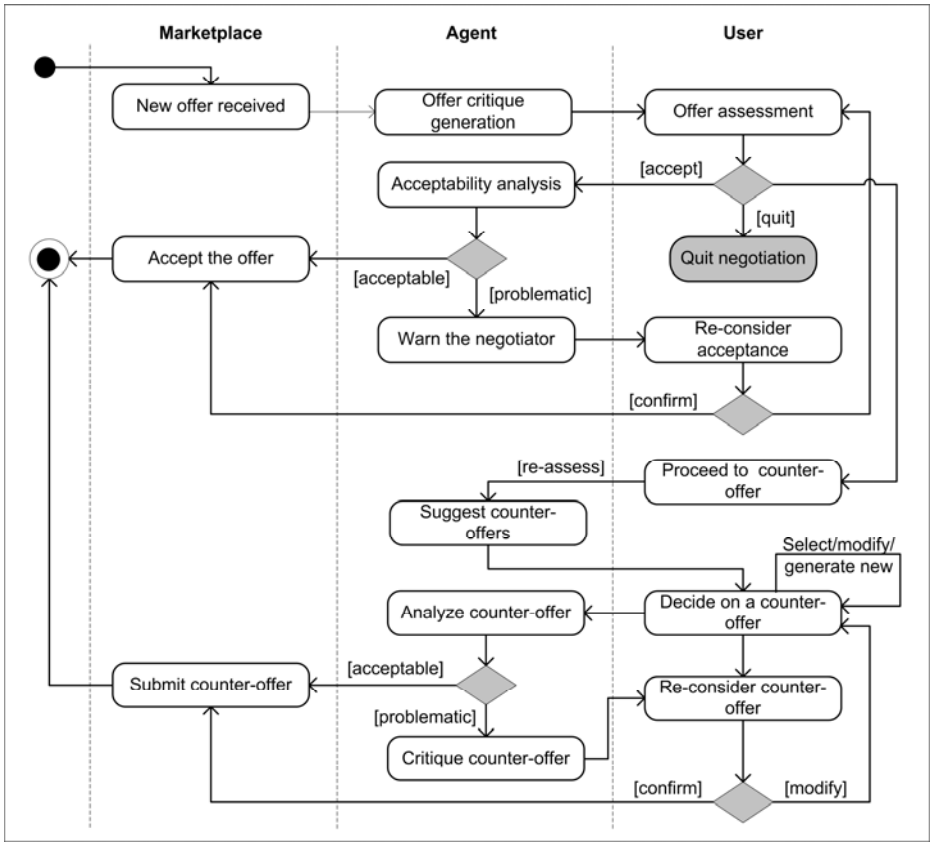

Figure 3. Decomposition of two protocol actions and their assignment to negotiator and agent

Continuation of the negotiation may involve addition of new issues and options, revisions of the preferences and selection of another negotiation strategy. It is important to update the negotiation situation so that it reflects the changes in the negotiator's objectives and preferences, since the quality of all the agent's recommendations and critique depends on the accurate representation of the user's preferences and selected strategy.

In the counter-offer construction activity, the agent generates a small set of candidate offers based on the adopted strategy and preferences in accordance with the offer generation procedure (see Section 3.1). These recommendations are presented as "viable alternatives" to the user, who then chooses the most suitable one. Thus, we avoid providing the user with the single "best" move, recognizing the fact that there could be a certain level of imprecision in capturing the user's implicit preferences. The user may also generate and evaluate his/her offers that are different from the agent's suggestions. This freedom gives negotiators control over the agent, whereas in automated negotiation the agent dictates the offers to be made.

Once the user decides to propose an offer, s/he will submit it to the system. At this point, the agent starts examining the submitted offer in order to decide whether any intervention is needed. If the agent

is able to find a match between the offer characteristics and one of the critiquing rules, the critique message is generated and displayed to the user as a warning signal. In this case, the user may decide to ignore the message, or to revise the offer. If the agent sees no obvious reasons to interfere, the offer will be submitted. In essence, the agent acts as a virtual negotiations advisor to the user, helping the user to interpret opponent's offers, proposing a set of options to the user and "watching over the shoulder" of the user in the counter-offer submission process. We consider this approach is more natural for the potential users than a traditional "toolbox" approach that simply makes various analytical tools available to the user, as it does not require that users have advanced technical or decision analytical skills.

4. eAgora architecture

The architecture of eAgora follows the *n-tier* architectural design specification, used in *e*-business systems development (Fournier 1998; Buffam 2000). The *n*-tier architecture is based on the software server concept. In eAgora, the following servers are used: (1) an application server (Macromedia ColdFusion) for the construction of dynamic web pages and execution of applications, (2) a database server (Microsoft Access used for the prototype) for the execution of decision and negotiation protocols stored in a database, and the storage of users' and programs' inputs and outputs and (3) a HTTP-server (Apache).

The 4-tier architecture implemented in eAgora is presented in Figure 4; in addition to the servers comprising three tiers, the 4th tier is the client's browser.

eAgora is implemented using the Fusebox development methodology (Peters and Papovich 2002), which provides a high level of modularity and flexibility. The application modules are independent components (fuses) linked through the Fusebox engine (see Figure 4). The Fusebox engine also parses elements of the web pages and passes them to the ColdFusion server, which sends them to the HTTP server.

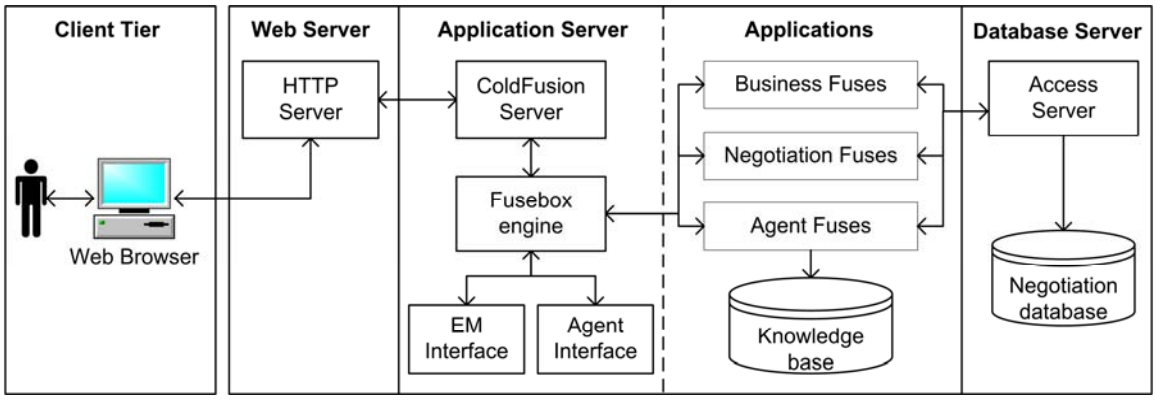

Figure 4 Decomposition of two protocol actions and their assignment to negotiator and agent

The eAgora architecture includes the business, negotiation and agent fuses as functional components. The business fuses determine activities allowing users to manage their negotiations. For example, the business fuse, *display_current* shows users all their current negotiations. The negotiation fuses perform actions discussed in Section 2, and the agent fuses perform actions discussed in Section 3.

The knowledge-base consists of the rules that govern the agent's behaviour. For example, they implement the fuzzy logic analysis in offer generation. The negotiation database contains the tables and relationships used to store the data required for and generated by eAgora.

The unification of all these parts in the 4-tiers provides the necessary e-marketplace functionality for buyers and sellers to perform negotiations with or without the support of an intelligent agent. The following section illustrates the concepts described by providing a concrete example of a negotiation in eAgora.

5. An example of a simple negotiation

In order to illustrate the functioning of eAgora, this section describes a concrete negotiation scenario. The purpose of the example is to present the flow of the processes and selected activities undertaken by the negotiators and the agent.

Maria, the seller, registers the product name (car), provides the product description (2000 Toyota, Corolla), specifies her role and requests the agent's assistance (enabled). She continues by specifying the negotiation issues with the exception of price which is the default issue (in the current version of eAgora bartering is not allowed).

The two additional issues are: warranty and winter tires. While in real-life negotiations more issues could be considered, for the purpose of illustration we consider here only a few issues.

The involvement of the agent requires that Maria enter at least two extreme options for each issue, one option represents her reservation level and the second represents her aspiration level. She may also enter intermediary options, i.e., options that are in-between the two extremes. The value of the alternative comprising all reservation levels is set to zero. Subsequently, Maria enters her preferences for every issue.

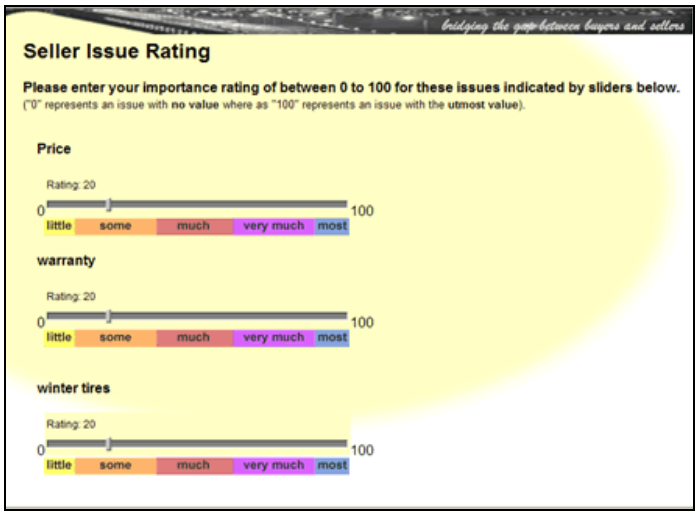

Figure 5 An example of preference elicitation

The preference elicitation form is shown in Figure 5. It is a user-friendly screen with clear labelling

and GUI elements to ensure that the users can communicate their preferences.

Maria specifies her preferences for the three attributes: price, warranty and winter tires (see Figure 5). This completes the preliminary dialog with eAgora. Maria now needs to wait for a potential buyer to join the newly created negotiation instance.

Bob, a potential buyer enters eAgora and reviews products for sale. He is interested in buying a car and joins the negotiation established by Maria. He uses eAgora to ask Maria to make the first offer. Maria, as illustrated in Figure 6, reviews her negotiations and realizes that Bob joined the "car negotiation" and is waiting for her offer.

Figure 6 List of Maria's current negotiations

Maria made an offer, which Bob rejected. He decided to continue the negotiation and made a counter-offer. Maria reviewed Bob's counter-offer and noted that its value was −100 (see Figure 7). The offer's negative value indicates that it violates some or all reservation levels.

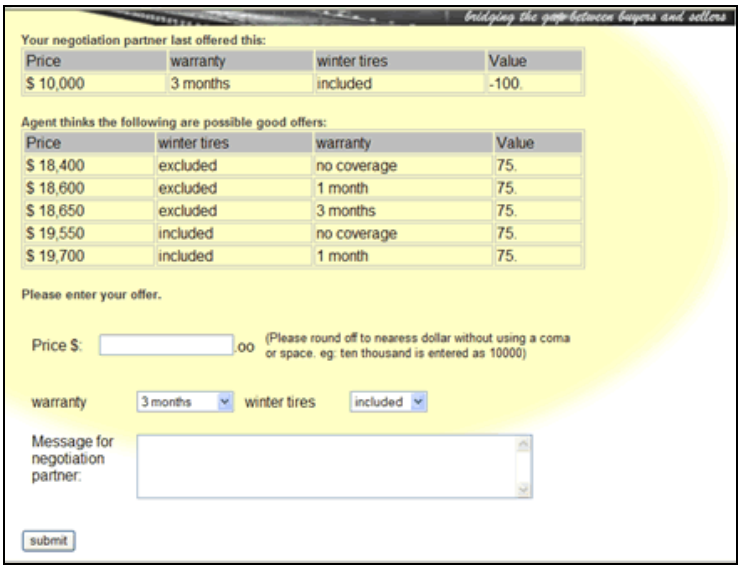

Figure 7 Screenshot of Maria's offer construction

Maria decides to continue the negotiation. She requests that the agent suggest candidate counter-offers to Bob's offer. The agent suggested five candidates. She could select one of them and send it to Bob.

Alternatively, she could decide to ignore the agent's recommendation and formulate her own offer (see Figure 7).

The agent suggested offers (packages) based on calculations using the negotiator's strategy, previous offers, latest offers received from the opponent and the number of negotiation rounds.

Suppose Maria has submitted the package {Price = $18,000; Warranty = "No coverage"; Winter tires = "Excluded"} as an actual offer to Bob. Bob's agent examines this offer in light of Bob's preferences and generates critique as shown in Figure 8. The critique refers to the value of the offer based on Bob's ratings; the agent advises Bob to make a counter-offer because Maria's proposal does not even meet his reservation point.

Figure 8 The agent's critique of a received offer

eAgora allows any of the negotiating parties to add new issues to the on-going negotiations. Bob utilizes this feature to introduce a new issue; this issue (called *inspection*) pertains to whether the seller or buyer is to bear the costs of the car inspection. By doing so Bob must obtain Maria's consent to have inspection as an issue in their negotiation. Otherwise inspection will not be added to the list of issues. Maria agrees to add *inspection* to the set of negotiated issues.

Addition or removal of an issue requires that both negotiators update their preferences in a similar manner as they conducted specification of their initial preferences (see Figure 5).

Bob revises his preferences and subsequently makes the following offer: {Price = $14,000; Warranty = 3 months; Winter tires = Included; Inspection = Buyer pay}. Mistakenly, Maria decides to accept Bob's offer. The agent notes this action and warns her that the offer violates her reservation point (see Figure 9). That is, the agent informs Maria that the offer she wants to make has the value of -20. This value, which the agent calculated based on her preferences, is below the reservation level (set to zero).

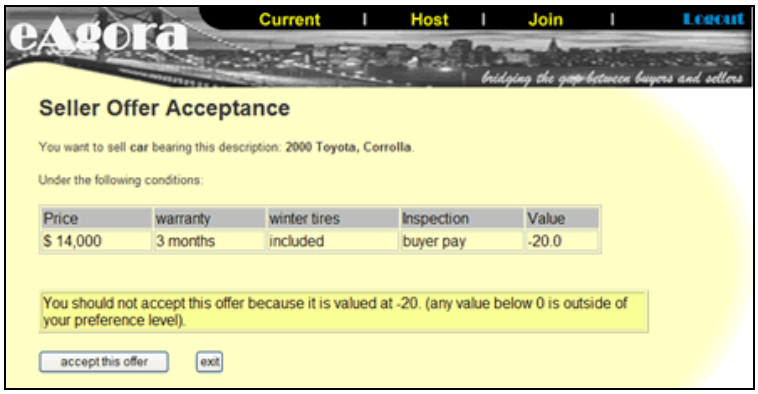

Figure 9 Screenshot of Agent's warning in offer acceptance

Maria decides to make a counter-offer and the negotiation continues until either an agreement is reached or one side walks away from the bargaining table.

6. Discussion and future research

In this paper we have introduced an agent-enhanced system called eAgora for supporting negotiations in electronic marketplace. We have described eAgora's protocol, models, prototype, and illustrated the approach using a specific case. Our belief in the utility of agent-supported negotiations is based, above all, on the following reasons:

1. The system invites the user to explicitly contemplate and specify his or her preferences and strategies adopted, thus inducing a substantive pre-negotiation analysis by the user.

2. The agent helps the user to avoid making crucial mistakes by critiquing offers and counter-offers from the point of view of the user's strategy and preferences. This reduces the possibility of prematurely settling on inferior offers.

3. The critiquing ability of the agent helps the user to realize the possible deviations from the strategy and preferences that were first adopted, and the need for their revision.

4. The agent minimizes the user's effort to determine promising offers thus saving effort and time. Once the preferences and strategy have been specified the task of selecting "promising" candidates becomes largely structured.

5. The possibility of revising strategies and/or preferences by the user leaves the user in control of the process. In this set up both the user and the agent are active participants in the offer construction process.

The dynamics of today's global business environment require that the organizations adopt a flexible approach to deal with customers and partners. Negotiations are the primary vehicle for providing such flexibility. However, this flexibility should be supplemented by a certain level of structure and sound organizational decision making so that organizations maintain control over their day-to-day operations. Agent-supported systems could serve as a means of providing such structure and control for the managerial negotiations and decision-making. Agents could act as rigorous advisors (one is

tempted to say "watchdogs") to facilitate consistent decision-making that adhere to the behaviour reflecting the adopted strategies and goals of an organization

In addition, we have conducted a preliminary usability test to determine the potential of the system and to identify concepts users may have trouble with in order to help set the ground work for the system revision and future experiments. Our primary interest was in the role of the agent and the users' perception of its usefulness. Therefore, the agent was active in one series of tests and inactive in the second series. The test results can only be considered tentative because of the small sample size.

A convenient sample of twelve individuals was used for the testing. The subjects were divided into six buyer-seller pairs, who constructed their own negotiation problem consisting of two to five issues. A pre-test questionnaire was filled out by the participants to determine their expertise level in e-negotiation and Internet usage. Next, a demonstration of eAgora was given to show all the features and functionalities of the system, after which participants were asked to first conduct a negotiation using eAgora without an agent, and then they were requested to start a new negotiation with the agent's involvement. During the process, comments and questions were recorded, and after each negotiation a questionnaire was completed based on their experience with and without the agent.

The results show that 92% of the participants are in favour of employing eAgora to buy and sell products over the Web. They liked the fact that issues can be added during negotiation, and that eAgora is easy to use. One user noted that:

> *eAgora is like the classified section of the newspaper, but much more. You can negotiate with the seller or buyer right away and have a deal ready before you go and meet them. This can save you time and money.*

In addition, 83% of individuals claimed that the agent provided helpful advice and suggestions in their negotiations, and everyone expressed an opinion that with the agent they felt in control of negotiations at all times. Another user made the following comment about the agent:

> *The agent was very useful because it gave me several suggestions on what to offer my opponent, and it helped me understand the value of the offers that I got.*

The agent's presence seems to be positively correlated with an increase in successful settlements. However, the preliminary test also found that users would like the possibility of having different protocols that would give them access to different strategies and tactics beyond the four strategies discussed in Section 3.1. The participants also requested that the agent should be enhanced by the capability of suggesting negotiation strategies rather than passively accepting the one selected by the user.

Future work on eAgora and its assessment will involve the modification and revision of the system components. This will include the replacement of Microsoft Access database with MySQL server and update of the Fusebox methodology to Fusebox 4.

In order to evaluate the full potential of eAgora, further testing is required with different user groups and products described by a few as well as by many attributes. This will include a full-scale laboratory experiment involving control and treatment groups with eAgora, with and without the use of the agent. A variety of outcome, process and perceptive measures should be used in such experiments in order to assess the effectiveness of agent-based negotiation support. Our short-term objective is to employ eAgora as a medium to study behavioural, commercial and social aspects of e-marketplaces and e-negotiation processes. The long-term objective is to enhance eAgora for possible application to

business transactions.

Another topic for future research is to investigate new ways of enhancing agent capabilities. Different possibilities in this respect include: incorporating real-time information search on demand by an agent, adaptive tracking of user profile based on the offers made; and profiling the opponent in order to infer the most likely directions for compromise and mutual benefits. Other directions include the implementation of various negotiation and auction mechanisms and the study of their efficacy in different contexts defined by problem complexity and users' characteristics.

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