NEGOTIATION SUPPORT SYSTEMS AND SOFTWARE AGENTS IN E-BUSINESS NEGOTIATIONS

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ABSTRACT

Experiments with negotiation software agents' in frictionless commerce indicate potential for destructive behaviour. Most of the agents are capable of engaging in auctions and have no ability to conduct complex business negotiations. Recognizing that people and software agents operate in different although overlapping spheres we propose an environment in which negotiation and decision support systems work together with software agents in electronic negotiations. Based on our experiences with the Inspire system we constructed an environment comprising software agents, and negotiation and decision support systems. One agent monitors the process, facilitates the use of Inspire, interprets the negotiators' activities and provides methodological advice. The architecture of this environment is based on the separation of user support functions from the autonomous software activities, separation of the support for individuals from facilitation and mediation; and scalability and the ability to provide linkages with the existing software.

INTRODUCTION

Auctions and electronic negotiations are considered an important part of e-commerce [1-3]. Auctions, which have very small transaction costs, are now being used to conduct many transactions among businesses and between businesses and consumers. The most important and appealing features of auction systems are process efficiency, ease of use, their reach and their ability to simultaneously manage very large numbers of bidders. An important aspect of auctions is their ability to manage the ambiguity and uncertainty of value in social context [4].

Internet auctions gained such popularity that some researchers consider them as the only effective coordination mechanisms for e-commerce [5-7]. Segev and Beam [8] summarize this trend by proposing:

> "… a new market-based negotiating paradigm, designed for the capabilities of electronic software agents on the Internet. We propose replacing negotiating skill with market forces. This is a direction which has already gained some momentum with the use of online auctions, and we believe it will continue to gain in popularity."

Auctions focus on determining the value of products through a process that is managed by one side. In contrast, the negotiation is a process that is managed by all the participants who co-operate to create value. Auctions deal with known and well-defined objects while negotiations are about defining these objects and modifying the participants' own perceptions and preferences. This allows for ill-defined and difficult issues to be negotiated, and for engagement of subjective perspectives in creating a shared meaning.

A negotiation is a process that is typically more costly than an auction in terms of time and effort required to achieve a solution from the parties. Since not all potential buyers and sellers are involved, negotiation is also prone to inefficient solutions in terms of market efficiency. These, however, are not sufficient reason for replacing negotiations with auctions. The two mechanisms are complementary and negotiations are used in many situations in which auctions should not or cannot be used. Negotiations require rich communication; they involve learning, accommodation of positions, construction of alternatives and modification of constraints. The outcome of a negotiation is often more than the negotiated product or service, the parties may establish a lasting relationship and engage in other transactions. The rich communication and learning allow gaining better understanding of the product; it's characteristics, use, warranty etc. The negotiation may also result in product redesign to better suit the requirements.

Internet technologies reduce costs of both auctions and negotiations, and introduce new tools to access, conduct and analyze these transaction processes. Electronic auctions have many of the market characteristics including very small information and coordination costs, and ability to attract a large number of participants. While electronic negotiations (e-negotiations) are less costly in terms of coordination and information exchange, and allow engaging more participants than the face-to-face negotiations, their principal characteristics remain the same. The lowering of transaction costs is less relevant in negotiations than in other transaction mechanisms. What is important to negotiators is the ability to: (1) expand the communication channels, (2) increase access to information and expertise, and (3) strengthen their cognitive and analytical capabilities.

The complexity of negotiation processes and the difficulty

that they pose to participants are behind many efforts in constructing analytical models and negotiation support systems [9-12]. E-commerce and electronic markets lead to new projects including research on the use of negotiation software agents [13-15]. In most cases, however, there is a distinction between the use of software agents and negotiation support systems.

Negotiation support systems (NSS) are designed to help and advise negotiators; they are used to structure and analyze the problem, elicit preferences and use them to construct a utility function, determine feasible and efficient alternatives, visualize different aspects of the problem and the process, and facilitate communication. Recently, several NSSs have been deployed on the web and used for teaching and research purposes as well as for conducting business negotiations.

Software agents are playing important roles in e-commerce especially in the automation of mundane operations [1]. Several software agents have been developed with the purpose to assist buyers in the search and selection of products. Some facilitate the linkage of buyers and sellers; others search for products that are of interest to the consumers. In general, an agent is a computer program that is situated in some environment; it is continuously active, capable of autonomous action (either proactive or reactive), and of work on tasks on behalf of its user [16, 17]. These programs differ from regular software because they are personalized, continuously running, and to a certain extent autonomous.

At present and in the near future the software agents may be capable of participating in auctions and in the simplest forms of negotiations. The social aspect of actions is in the determination of acceptable or optimal price; the social aspect of the negotiation is in the establishment of a relationship and understanding. While the former might be done with the help of software agents, the latter requires the parties' direct engagement and intervention. This is because the parties need to understand themselves and each other, the negotiated problem and the possible implications. The communication, formulation of offers and making concessions is a vehicle for both a consensus and understanding. The agents are "blind to the complex social trade-offs between goals, rules and the social fabric. ... Experiments at both IBM and MIT with bots in apparently frictionless markets indicate potential for destructive behavior." [18, p. 51-52].

The need for the parties' direct participation in the negotiation does not alleviate the parties' need for support and advice. Experiences from the Inspire system and its acceptance by the users and their suggestions led us to suggest an integrated software environment to aid negotiators throughout the negotiation process and to provide methodological support and advice [19]. There is a role for both NSS and NSA in e-negotiations as we propose it in this paper. In that we concur with Brown and Duguit [18, p. 62] that:

> "… bots and humans operate in different, if overlapping spheres. By redefining one as the other, or reducing both to information-processing or goal-pursuing agents, these differences are submerged or confused. … In general, it will be better to pursue not substitution but complementarity. … But complementarity requires seeing the differences between information processing agents and human agency."

An integrated environment supporting Internet negotiations is presented in this paper. The discussion is based on our experiences with the development and implementation of Inspire and INSS, two Internet-based negotiation support systems [12, 20], the framework for the Inspire extension [19] and the evaluations made by over 4000 users. In Section 2 we discuss negotiation support systems and software agents. In Section 3 the Aspire environment comprising of a negotiation support system (Inspire), a negotiation software agent (Atin), and other systems is presented. Design and implementation issues are presented in Section 4. Discussion on the future work and planned experiments concludes the paper.

NEGOTIATION SYSTEMS AND AGENTS

Negotiation Support

NSSs are designed to facilitate the various phases of the negotiation process such as understanding the negotiation case, assigning preference ratings for negotiable issues and options, and setting the reservation level before the negotiation begins. The tools for support are varied and they include decision science methods (e.g., decision tables, decision trees, multi-attribute utility theory), statistical methods (e.g., forecasting, regression analysis), and game theory.

NSS support ranges from systems that help negotiators prepare for a negotiation, to mediation and interactive systems that restructure the way negotiations usually take place [21]. The foundation of NSS is decision and negotiation analysis [22, 23]. Negotiation analysis integrates decision analysis and game theory in order to provide methodological support to users. Negotiation analysis is aimed at bridging the gap between descriptive qualitative models and normative formal models of bargaining. This approach adopted a number of behavioral concepts (e.g., reservation values, BATNA, integrative/distributive negotiations and principled negotiations) and incorporated them into quantitative models [24]. This allowed advisors to conduct formal analysis of negotiations in order to provide support.

Rangaswamy and Shell [21] distinguish between NSS for preparation and evaluation and NSS for process support. Preparation and evaluation systems operate away from the bargaining table to help individuals privately organize information, develop preferences, refine pre-negotiation strategies, or evaluate negotiation offers. Process support systems operate at the bargaining table; the systems are designed not only to assist parties in gaining a subjective representation, but also to help negotiators move toward integrative settlements [25]. Process support systems can provide a mediation function and individual support function. Systems that focus on mediation interfere in the process and prompt the parties to agree on a compromise. Systems that focus on individual support provide the parties with analytical and

visualization tools, and with communication facilities.

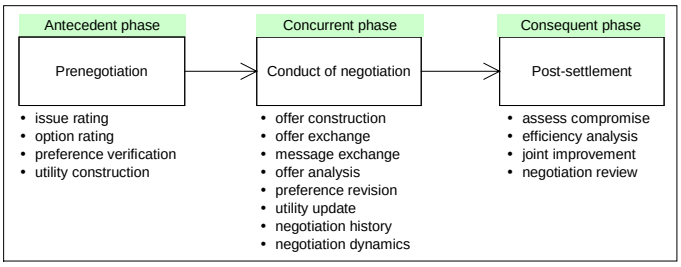
Inspire system

The Inspire system has been used as a research tool for the InterNeg group to study cross-cultural negotiations over the web [12, 20]. It is also used to study the impact of decision analysis on the negotiation process, the role of support in negotiation and the role of explanatory and display facilities on users' perception and decision-making.

The decision support functions implemented in Inspire include preference elicitation, construction of the utility function, quantitative evaluation of offers, maintenance of the negotiation history and graphical representation of the negotiation dynamics. The communication support functions include the exchange of structured offers with accompanying arguments, free-text messages and automatic email notification of the opponent's activity.

An important feature of negotiations with the Inspire system is the structure of the process. Inspire supports the three stages of negotiation illustrated in Figure 1. The negotiation progresses through three distinct phases: pre-negotiation analysis, conduct of the negotiation, and post-settlement as discussed in section 2.2. The support of Inspire in the three phases is illustrated in Figure 1:

FIGURE 1. NEGOTIATION PHASES AND ACTIVITIES SUPPORTED WITH INSPIRE



During the pre-negotiation phase, Inspire helps the user to better prepare for the negotiation. The activities include helping the user to understand the negotiation problem, the main negotiable issues and offers, and some possible combinations (which may form the basis of offers and counter-offers). The user defines his/her own preferences and the system takes the input from the user to construct the utility function.

The negotiation phase in Inspire may begin with the construction of an opening offer. There is a pre-defined format for offers – each offer contains user-selected options (issue values) for each of the negotiable issues. An offer may be accompanied with a free-text message, which allows the users to communicate directly. Inspire provides a numeric rating for each offer sent/received, which represents the "goodness" of the offer. This rating is calculated based on the user's utility function. Users may also review their negotiation history, or review and revise their preference ratings during the negotiation phase. A graph displaying the dynamics of the negotiation is also available.

Once a compromise is achieved, the Inspire system acts as a mediator and checks for its efficiency (Pareto-optimality). The system takes into account both users' utility functions, and determines if any further improvement can be made to the agreement. If the compromise is inefficient, the system computes efficient packages and displays a few to both users, which allows them to re-negotiate.

Negotiation software agents

Software agents are programs that carry out certain operations on behalf of a user or another program with some degree of independence or autonomy and, by doing so, realize a set of goals or tasks for which they are designed [26, 27]. The reasoning mechanisms of software agents can range from a set of simple "if-then" rules to sophisticated machine learning algorithms such as neural networks or Bayesian networks [16, 28].

Software agents that can carry out negotiation activities on behalf of users are known as negotiation software agents (NSA). Their purpose is to automate different negotiation tasks arising from buying and selling products over the Internet [2, 14, 15, 29]. Despite the claims made by the NSA developers, the use of negotiation methodologies is often over simplified and the systems engage in bidding or simple single-issue negotiations with predefined behaviour, strategy and tactics. MarketMaker, AuctionBot, and Tete-a-tete are examples of agent-based systems that seek mutual agreements on the terms of transactions that satisfy the parties' predefined constraints, preferences and objectives. These agents engage in the information exchange activities that are typical to auctions rather than negotiations but are not capable of engaging in context rich and complex negotiations [1, 14, 30].

One of the better-known systems, MarketMaker, is a multi-agent system developed at the MIT Media Lab, which facilitates auctions in an electronic marketplace [15]. A seller may post a product for sale through the selling agent. Interested buyers post their bids with the help of their buying agents. Both parties define their desired and worst acceptable price, as well as the slope for making concessions to their agents at the initiation stage. The agents submit bids and monitor the negotiation process, however, the human user makes the final decision. MarketMaker supports web auctions rather than negotiations. The system is rigid and allows for only single attribute transactions – price; hence the communication process is very narrow. Instead of exchanging negotiation offers and information, the agent posts a new bid (upon the approval of the user) once the market information is updated.

From our point of view, negotiation software agents may take over well-defined and structured activities in a negotiation but it is not necessary for agents to handle all the tasks. For example, the agent may present offers, seek for information about similar negotiation situations, collect information about the counter-parts, and alert the principal if pre-defined conditions are violated. The ill-defined and ambiguous issues, decisions regarding relationship between the parties,

modification of the rules and parameters are better left to the principals.

Kersten and Noronha (2000) propose negotiation software agents that provide information and knowledge (e.g., statistics and inferences) about past negotiations, scan the negotiation transcripts and other process descriptions, followed by comparing of situations, interests and issues of past problems against the current problem. These agents may also receive knowledge from various sources, such as other agents, the environment, user input and databases, then interpret and understand that knowledge and intelligently use information to assist the negotiator throughout the negotiation processes [31].

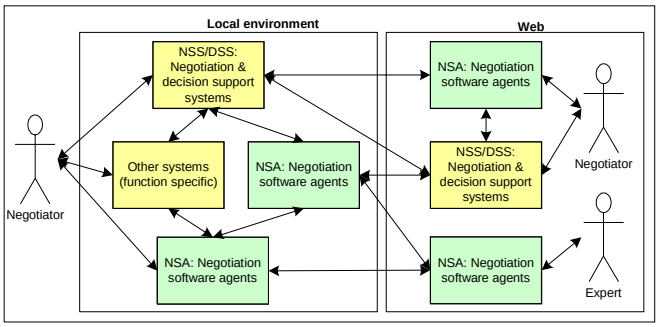
The possible functions of such agents largely depend on their degree of autonomy, the type of the negotiation, and the specificity of the principal's directives. The functions depend also on the agent's interactions with other systems and agents. The agent may be highly specialized and may cooperate with other agents, interact directly with the principal, or it may communicate via a decision support system (DSS) or a negotiation support system (NSS) that supports the negotiators in the construction of problem representations and in their assessment and modification. The agent may suggest new issues/options and innovative (for the principal) approaches to cope with conflict based on the information obtained from experts and extracted from other negotiation histories.

Complementary systems

Negotiating software agents (NSA) should not be discussed with the focus solely on the agents' abilities and behavior. Consideration should be given to their principals. The NSA acts on behalf of the principal, communicates with the counterpart, and has significant autonomy in decision-making but the decision problems are well defined. In contrast, NSSs have very limited autonomy and their purpose is to help the principals understand the problem, express their preferences, represent the process and formulate the exchanges. NSSs supports direct negotiations and are process-oriented, the objective of NSSs is to facilitate the process and provide support so that the users can achieve good and/or satisfactory results. NSAs are goal oriented, their objective is to perform a task or meet an objective and the process of achieving it is not an end in itself. Thus, very simple negotiations and those that can be converted to bidding can be delegated to NSA, while those that are difficult require NSS.

Complex and rich processes comprise both routine and simple tasks as well as tasks that are original and require imagination. Business negotiations are often such processes requiring that both NSS and NSA technologies be utilized. There is a need to develop tools and infrastructure that can support some and conduct other activities. In business-to-business negotiations flexible and extensible tools are needed to support both integrative and distributive activities. These tools have to be highly interactive and competent at managing the complexity of multilateral business-partner relationships, especially since each business negotiation tends to be different from all the others, in small, but important, ways.

FIGURE 2. CONFIGURATION OF COMPLEMENTARY SYSTEMS



A particular architecture depends on, among other things, the complexity of interactions with the principal, level of support required, and the requirements for information processing by other systems (e.g., financial, marketing and production). In Figure 2 we present a high-level architecture in which the negotiation environment comprises a principal (negotiator), NSS, function-specific systems and two NSA. One of the key configurations, which is especially relevant to the design of digital marketplaces and other electronic environments comprising economic agents, is that of autonomous software agents performing well-structured tasks, controlled by NSS performing relatively ill-structured tasks, which are in turn controlled interactively by humans. This recognizes the fact that there are activities that each of the three system types does so well that an alternative type of system cannot replace it.

Rubin and Sander [32] suggest the use of skilful human agents in representative negotiations. One of the reasons to engage in this type of negotiation is that the agents have expertise that the principals lack, and they are more likely to make more favourable agreements. The agent can be a consultant or an advisor, who provides strategic advice and assists the principal during the negotiation. This led us to consider a system in which NSA would guide negotiators throughout the whole process of the negotiation, and provide extensive support and advice whenever appropriate [19]. The agents can, as indicated in Figure2, request information from other agents and from experts.

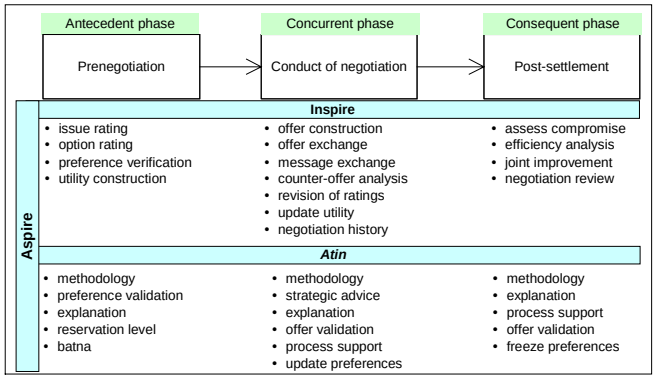
ASPIRE

Aspire framework

The Aspire system is an integration of Inspire, an existing NSS and Atin, a NSA. The activities and tasks undertaken by Inspire and Atin are presented in Figure 3. Inspire's emphasis is on negotiation analysis and quantitative support; the system interacts with the user and it is under the user's full control. The main role of Atin is to monitor the negotiation process in order to provide a full range of methodological support, including the assessment of the user's activity, suggestion of possible strategies, tactics and offers, and an-

swers to the user's questions.

FIGURE 3. ASPIRE SUPPORT IN THE THREE NEGOTIATION PHASES



Atin acts independently from the user and it continuously observes the user's activities and the negotiation process. Its focus is on the negotiation methodology and the user's adherence to the "arts and science of negotiation". Atin's flexibility and advisory character implies that the user may ignore the agent's suggestions and recommendations. This is not the case with Inspire, which has to follow one from number predefined paths of interactions.

Architecture

The Aspire prototype is an implementation of the configuration of complementary systems illustrated in Figure 2. Atin is a new addition to the Inspire system and it's construction follows the *n*-tier architectural design specification [33], including the web client, the http server, the application server (consists of the NSS and NSA), and the database and knowledge base server.

Atin is a standalone system embedded in the application server that continuously interacts with the Inspire system. This loosely coupled architecture provides flexibility allowing for replacement of Inspire with a different NSS, and addition of additional NSAs, and changing of the scope of NSAs activitiies and their level of independence without affecting the NSSs.

The Atin negotiation software agent retrieves information from the database and knowledge base, and provides advice to the negotiator. Atin provides suggestions to the users based on its knowledge base and the database. The user database stores all activities of each negotiator (e.g., preference ratings, offers and messages sent, etc.) and will be used by both the NSA and NSS. At certain stages in the negotiation, the negotiator may request support from Atin by asking questions. In order to provide suggestions, Atin may request some additional information from the user (e.g., negotiation strategy, willingness to make concession, etc.). These inputs from the user will help the agent to filter out irrelevant information, and display the most appropriate advice.

Information submitted by the negotiator (e.g., an offer or a message) is passed to the Inspire engine. Inspire handles communication between users (in this case, sends an offer to the counterpart via the message engine), saves the user activity in the user database, as well as performs decision support activities (e.g., return the numeric utility value to the user after computation). It also invokes the user's negotiation assistant – Atin. The agent receives the user input, collects relevant information from the databases, searches the knowledge base, and returns appropriate suggestions (if any) to the user's web browser.

Atin's functionality

During the preparation phase, Atin assists the negotiator in structuring the problem. The agent can also help the negotiator in the preference elicitation and utility construction steps by giving comments and suggestions. Similarly it may help in setting the BATNA and reservation values. The pre-negotiation interactions between Inspire and the user, and Atin's activities are illustrated in Figure 4.

FIGURE 4. ASPIRE PRE-NEGOTIATION PROCESS

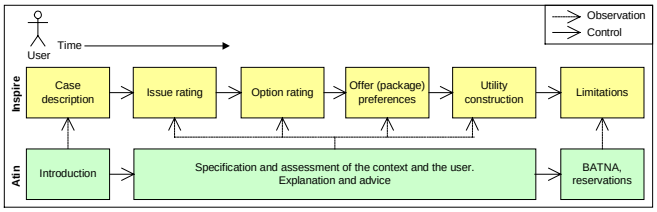


Figure 4 illustrates the pre-negotiation process in Aspire. The user logs in to the system, and Atin introduces itself and presents its features. The user may then read the negotiation case, evaluate the relative importance of the issues and available options to be negotiated, and make a comparative evaluation of several complete packages selected by the system. The agent checks the knowledge bases and advises the user, if there are any violations of the pre-defined negotiation rules, or if there is any appropriate advice to the user. In order to provide further support, the agent requests the user to provide his/her reservation values and BATNA values before moving on to the negotiation phase.

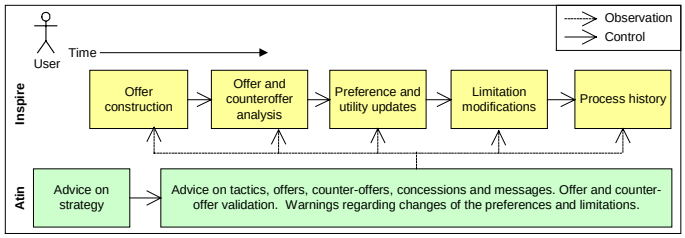
During the negotiation phase, Atin interprets the negotiator's activities and provides advice on negotiation strategies, suggests moves and possible alternatives. These activities are performed upon user's request. The agent alerts the user when BATNA and reservation values are violated. At any time, as indicated in Figure 5, the user may seek advice from the agent regarding tactics, counter-offers, concessions, and so on.

Upon request Atin may propose structured offers, which are based on previous exchanges of offers and the level of concession made by the user. For example, the agent may first ask the user to define a negotiation strategy (hard and positional bargaining, accommodating, or process and relationship oriented).

When the user receives an offer from the opponent, the agent may offer an assessment of the offer to the negotiator while the NSS provides a quantitative evaluation (i.e., numeric

utility rating). The agent also provides assessment of the process, the user's range of flexibility (based on the differences between the utility value of BATNA, and the reservation values of these issues, perception of relative power (based on the differences between the aspiration values and the highest utility value) and so on.

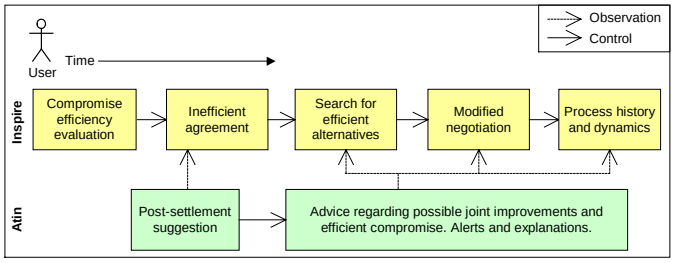
FIGURE 5. ATIN'S SUPPORT IN THE CONDUCT OF NEGOTIATION



Once a compromise has been achieved during the negotiation phase, Inspire checks it for efficiency (Pareto-optimality) and presents possible alternatives for joint improvement. Inspire takes into consideration the utilities of both parties and computes the efficient packages (alternatives) for the users.

The agent provides an explanation of why the user should seek efficient compromises and suggests that the user continue the negotiation. If both parties agree to continue the negotiation, Atin continues to support the negotiator providing advice similar to the negotiation phase. Figure 6 illustrates Inspire and Atin's activities in the post-settlement phase.

FIGURE 6. ATIN'S SUPPORT OF POST-SETTLEMENT ACTIVITIES



DESIGN AND IMPLEMENTATION

Rapid prototyping, simplicity, and extensibility are among the most important design criteria in building our integrated software environment. In the design of the components of the integrated negotiation software environment we continue to use the object-oriented and rule-based methodology which the Inspire and INSS systems are based on [20].

The use of object-oriented techniques can benefit the developers through code reusability, hence a design pattern is a set of co-operating objects or classes in a particular structural pattern that reappears in many implementations. The system requires nothing more than a web browser and an Internet connection that enhance its portability for our end-users. A rule-based methodology is easy to understand; each rule can be viewed as a unit of information in a knowledge base, which can be easily added or removed.

FIGURE 7. ASPIRE FIRST SCREEN

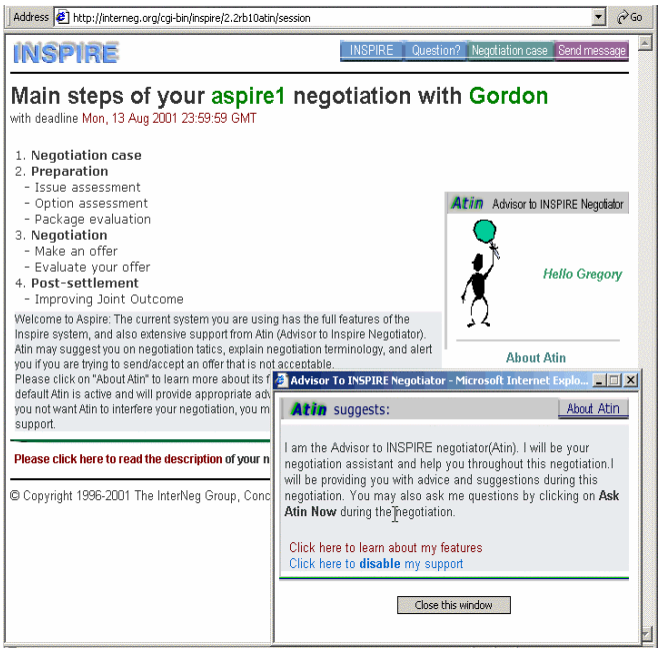
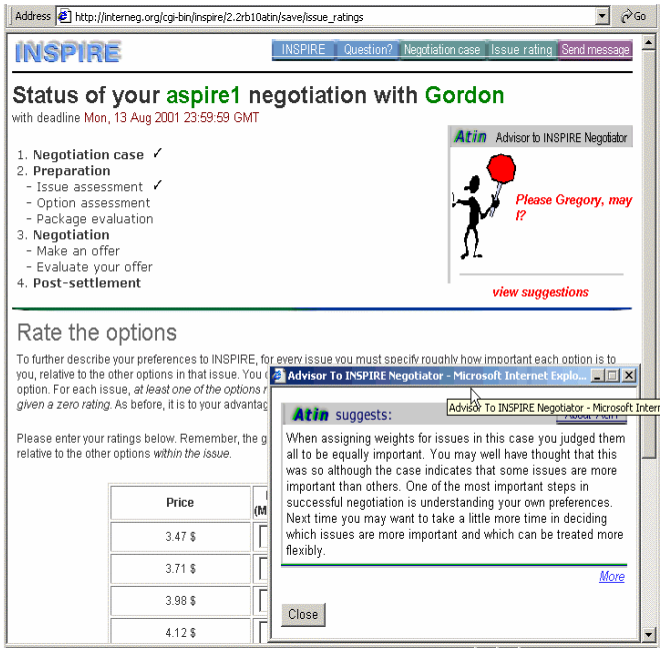


FIGURE 8. AN EXAMPLE OF ATIN'S ADVICE IN PRE-NEGOTIATION PHASE



Atin's interface consists of web pages that dynamically display appropriate messages to the user. The user may select their requests and enter any information to the agent. PHP scripts are used to run on server side for processing help and validation features. User input validation is handled by JavaScript programs. The use of this type of error checking

reduces the possibility of invalid input.

An opening screen of the Aspire system is presented in Figure 7. The Inspire component introduces the main steps that the user follows in the Inspire negotiation. A small window on the right introduces Atin. In order to make the agent unobtrusive the user may close the window or request additional information. To warn the user Atin uses simple road signs: a green sign (shown in Figure 7) indicates there is no warning, yellow indicates a warning, and a red sign (shown in Figure 8) means that Atin sees the user's particular move as incorrect. The three signs show the type of the message that Atin may have ready for display. The user may also ask the agent for assessment about past activities and advice regarding possible moves.

FIGURE 9. ATIN SUGGESTS AN OPENING OFFER

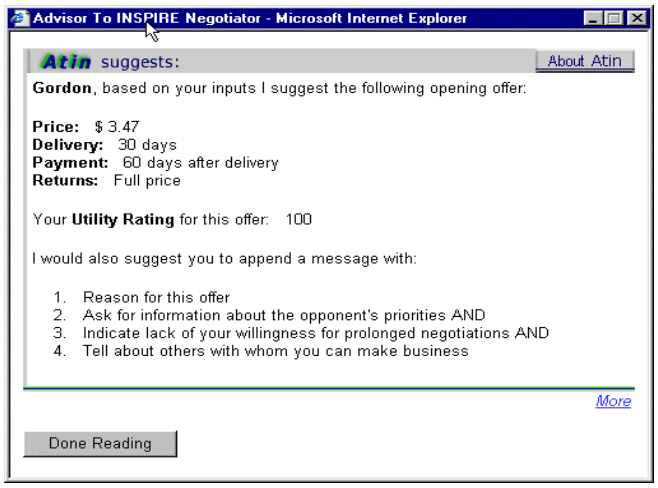


FIGURE 10. ATIN'S ALERT ON LARGE CONCESSION BETWEEN OFFERS

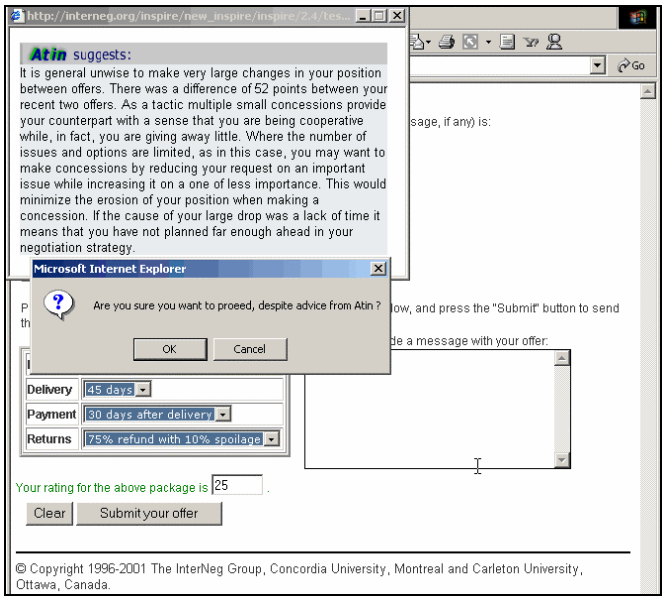


Figure 8 shows an example of Atin's suggestion when the user violates one of the issue ratings rules. Atin's suggestion of an opening offer based on the user's request and selection of a hard bargaining strategy is presented in Figure 9.

A significant drop in the utility value of the two consecutive offers made by the user causes Atin to alert the user and reconsider the offer before it is sent to the counter-part. This situation is illustrated in Figure 10.

USER EVALUATION

Two groups of users are invited to use the Aspire system. The first group of the users has used the original Inspire system within the past 12 months and the other group has never used any web-based negotiation support systems before. Negotiation cases are set up for the users and each of them plays the role of either a buyer or seller (depending on their case scenario description). The two groups of users are paired among each other randomly.

This arrangement was selected so that we can obtain feedback from both previous Inspire users and from new users. Previous Inspire users where asked whether (1) the Aspire system provides more extensive support to users than Inspire, (2) web-based negotiations become easier with the aid of an agent, and (3) the features they considered most/least useful during the negotiation. Novice users were queried about (1) their experience with Aspire, (2) the adequacy of support provided by an NSS-NSA integrated environment, and (3) the list of features considered helpful or detrimental in web-based negotiations.

Generally the feedback from the users has been favourable. For people who have used the Inspire system before, 90% found that the Aspire system has provided them more support, as well as been much easier to use compared to the original Inspire system. This conforms to our expectation that web-based negotiation becomes easier with the aid of an agent.

Users claim that the pop-up warnings from Atin play a significant role in both their decisions and their assessment of their own negotiation strategy. This indicates that such a feature could reduce the occurrence of certain negotiation pitfalls. One user made the following comment:

> "The pop-up warnings not only alerts the user on an unreasonable action they have made, but also reminds the user of some of the previously identified parameters in the pre-negotiation phase. I was too focused on my rating value and did not realize that my offer violates one of the bottom line values. These alerts also prevent me from overlooking important issues during the negotiation."

The users are also asked in the survey whether they feel in control during the negotiation. Over 78% stated that they are in control of the negotiation process and feel that Atin assists the negotiation without taking over the control from them. This conforms to our expectations, since we would like the agent to assist the user whenever required, but not taking over the negotiator's control.

DISCUSSION

The experiences with INSPIRE and INSS systems, users' suggestions, and the evaluation of the existing NSA led us to consider integration of NSS and NSA in a single software environment. The architecture of this environment is based on the separation of user support functions from the autonomous software activities, separation of the support for individuals from facilitation and mediation; and scalability and the ability to provide linkages with the existing software. This architectural approach allows complementing the support of users' own activities with the actions undertaken on their behalf but without their direct involvement. It also allows for the inclusion of support provided by support systems and external entities accessed with NSAs.

The development of Atin prototype, and the feedback from the users confirmed our assumption that a negotiation software agent will be a useful feature to support Internet-based negotiations. At present Atin does not have adequate knowledge to provide a truly comprehensive support. We continue working on expanding and enriching the negotiation knowledge base.

The next version of the agent will emphasise knowledge base development and varying scope of autonomy. Several levels of autonomy would allow the user to choose from various assistance levels, ranging from inactive to fully autonomous. We also plan to revise the Inspire system to accept reservation level, aspiration level, and BATNA values. Although Atin may request such information from the user, it would be more logical for the NSS to request such information while Atin can access it.

The explosive growth in electronic commerce has not reduced the complexity of negotiations conducted over the Web, partly due to human factors, and partly because the underlying economic models remain unchanged, despite the increase in speed, reach, and computational efficiency. The excitement and hype associated with the growth of the Web has engendered some hasty conclusions and misconceptions about the nature of Internet-based negotiation. Negotiations are really collaborative problem solving mechanisms and cannot be reduced to optimization problems relating to the efficient distribution of value. The nature of negotiations derives from the human ability to change the game, reformulate the issues, construct deep models of each participant's interests and world-views, and ultimately create new value beyond that anticipated through the initial model of the negotiation. Invariably, the negotiation process is itself negotiable.

These characteristics pose serious challenges to the design of autonomous software agents. The challenges cannot be scoped away by focusing on fully structured negotiation protocols such as auctions. For each economic model that drives a particular structuring assumption (e.g., manufacturers wish to reach a broader pool of customers, so they will structure their ontology (product description) to facilitate matchmaking via search agents), there is another economic model that has destructuring effect (manufacturers wish to avoid competing on price and will personalize products—create product discrimination to prevent match-making by independent parties). This richness in economic models and negotiation mechanisms implies that any e-commerce infrastructure designed to support constantly changing business environments must be designed from the bottom up to address the challenges raised in this paper.

The first step is to recognize that an effective infrastructure must support the creation and activity of both autonomous agents and DSS/NSS. This is required in order to exploit the power of the computational and communications infrastructure via the NSA (since they possess the advantage of speed, and can construct offers in milliseconds), and at the same time the intelligence of the humans through the DSS/NSS (since they have the robustness required to support problem restructuring and game changes). Moreover, humans often need to be in the loop to because they want to exert some level of control over the negotiation process. We have therefore emphasized the importance of the hybrid NSA/DSS/NSS architecture, anticipating that the independent agents may will be spawned or controlled by the systems which directly interact with the negotiators.

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