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Aspire: An Integrated Negotiation Support System and Software Agents for E-Business Negotiation

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Abstract. Feedback from several thousands of users of our Web-based negotiation support system has demonstrated that such systems can be used in e-business negotiations. Users' feedback also indicated that active support in the use of the system and negotiation methodology can facilitate the effective system use. This led us to develop a Web-based integrated negotiation environment capable of supporting negotiators, providing context-dependent advice, and undertaking certain activities autonomously. This environment comprises software agents, and negotiation and decision support systems. An agent monitors the process, facilitates the use of the Web-based negotiation support system, 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, scalability and the ability to provide linkages with the existing software.

Keywords: negotiation, negotiation support systems, Internet negotiations, e-negotiations, e-business, business negotiation support, software agents, decision support

1. Introduction

Recent technological advancements have revived and accelerated interest in negotiations in general and in particular in electronic negotiations. The impact of information technologies on negotiations is not limited to the use of electronic communication in addition to face-to-face communication. Technology changes ways the negotiation problems can be represented and the ways the negotiation process can be structured. Theoretical and applied research on electronic varieties of negotiations includes electronic auctions, negotiation support systems and automated agent-based negotiations (see e. g., [1-4].

Electronic auctions have very small transaction costs and therefore they are used to conduct many transactions between individuals and also 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 [5].

Internet auctions gained such popularity that some researchers consider them as the only effective co-ordination mechanisms for e-commerce [6-8]. Segev and Beam [9] 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. The rules for information exchange and offer structure are fixed and defined a priori. In contrast, the rules of the negotiation may be modified during the process and similarly the negotiated issues may be clarified and redefined. The negotiation participants often attempt to influence their counter-parts and in effect modify their perceptions and preferences. This allows for ill-defined and difficult issues to be discussed, and for engagement of subjective perspectives in creating a shared meaning.

Negotiation is a process that, in comparison with actions, is more time consuming and requires more effort from the participants. Because negotiations involve only a few participants, its solution, i.e., a compromise, cannot be assessed in terms of market efficiency.

Auctions and negotiations are complementary coordination mechanisms. Negotiations require rich communication; they involve learning, accommodation of positions, construction of alternatives, and modification of constraints. Learning and modifications allow the negotiators to achieve a compromise that was not considered feasible at the beginning of the negotiation. Furthermore, 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 may also allow gaining better understanding of the negotiated object, for example, product, its characteristics, use, warranty, etc. It may also help to better understand and assess the negotiation partners, their preferences, requirements and needs.

Internet technologies reduce costs of both auctions and negotiations. They 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 an ability to attract a large

number of participants. While *e-negotiations* (electronic 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 participants' 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 [10-13]. E-commerce and electronic markets lead to new projects including research on the use of negotiation software agents [14-16]. In most cases, however, there is a distinction between the use of negotiation support systems and software agents.

Negotiation support systems (NSSs) 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 [17, 18].

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 [19, 20]. These programs differ from regular software because they are personalized, continuously running, and to a certain extent autonomous.

The negotiation software agents (NSAs) may be capable of participating in auctions and in the simplest forms of negotiations. The social aspect of auctions is in the determination of acceptable or optimal price. In contrast, the social aspect of negotiations 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 behaviour." [21, p. 51-52].

The need for the parties' direct participation in the negotiation does not alleviate their need for support and advice. Our experiences from the Inspire Web-based negotiation support system, 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 [22]. There is a role for both NSSs and NSAs in e-negotiations as we propose it in this paper. In that we concur with Brown and Duguit [21, p. 62] that:[1]

[1] Brown and Duguit use the term "bot" to describe both robots and software agents.

> "… 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."

The purpose of this paper is two-fold: (1) to discuss the need for an integrated environment supporting Internet negotiations, and (2) to propose an agent-NSS environment, called Aspire, and test its contribution to support quality and user control as compared with an NSS. The discussion is based on our experiences with the development and implementation of Inspire and INSS, two Internet-based negotiation support systems [13, 18], the framework for the Inspire extension [22], and the evaluations made by over 4000 users of the Inspire system. In Section 2 we discuss negotiation support systems and software agents. In Section 3 we present the Aspire environment comprising of a negotiation support system (Inspire), a negotiation software agent (Atin), and other systems. Design and implementation issues are presented in Section 4. Discussion on the future work and planned experiments concludes the paper.

2. Negotiation systems and agents

2.1 Negotiation support

Negotiation support systems (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 [23]. The foundation of NSS is decision and negotiation analysis [24, 25]. 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 behavioural concepts (e.g., reservation values, the best alternative to the negotiated agreement-BATNA, integrative/distributive negotiations and principled negotiations) and incorporated them into quantitative models [26]. This allowed advisors to conduct formal analysis of negotiations in order to provide support.

Rangaswamy and Shell distinguish between NSS for preparation and evaluation and NSS for process support [23]. Preparation and evaluation systems operate away from the bargaining table to help individuals 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 the construction of a subjective representation, but also to help negotiators move toward integrative settlements [27]. Process support systems can provide both mediation function and individual support function. Mediating systems interfere in the process; they may suggest concessions and a compromise, and prompt the parties to reach an agreement. Systems that provide individual support have tools for problem formulation and analysis, solution and offer assessment, and communication facilities.

2.2 Inspire system

The Inspire system supports bilateral negotiations conducted on the Web. The system was developed in 1995 as a part of the InterNeg project (http://interneg.org), which is a research and training project focussed on negotiation and e-negotiations. The system has been used in teaching several thousands of students, engineers, lawyers, and managers since 1996. Inspire is also a research tool for the InterNeg group to study cross-cultural negotiations over the Web, and 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 [13, 18, 28].

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 counterpart's activity.

An important feature of the Inspire negotiations is the structure of the process. The negotiation progresses through three distinct phases: pre-negotiation analysis, conduct of the negotiation, and post-settlement. In each phase Inspire provides support. The three phases and the supported activities are presented in Figure 1.

During the pre-negotiation phase, Inspire helps the user to better prepare for the negotiation. The support activities include helping the user to understand the negotiation problem, the main negotiable issues and offers, and providing some possible combinations of issue values (which may form the basis of offers and counter-offers). During this phase 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 predefined format for offers – each offer contains user-selected option (issue value) for each of the negotiable issue. An offer may be accompanied with a free-text message, which allows the users to communicate directly. The user may also begin the negotiation with sending a message without an accompanying offer.

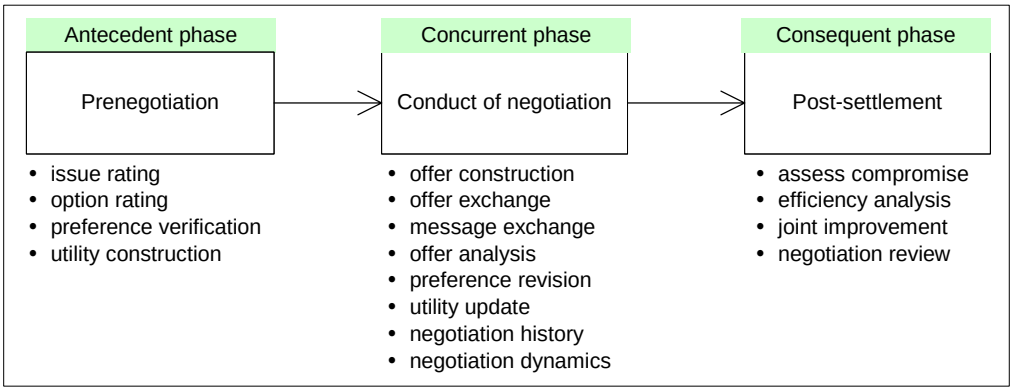

Figure 1. Negotiation phases and activities supported with Inspire.

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. At any point during the negotiation users may review their negotiation history, or review and revise their preference. They can be dis-

played in terms of a complete transcript of offers, counter-offers and messages, or as a graph displaying the offers and counter-offers in the user's utility space.

Once a compromise is achieved, the Inspire system acts as a mediator and checks for the compromise efficiency (Pareto-optimality). In this phase 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.

Inspire negotiations are conducted over a case of business-to-business transactions. Typically, they take up to three weeks. The process may result either in a compromise, or the parties may not reach a compromise before the deadline or one party may terminate negotiations at any time. This last possibility allows users to reject offers that are bad for the companies they represent. The user who terminates his/her negotiation may immediately request a new negotiation and is assigned another partner.

Upon completion of Inspire negotiations, the users are requested to fill-in a post-negotiation questionnaire. Generally, users find the system very easy to use, and their evaluation of the overall system is favorable. One of the questions refers to the users' overall assessment of the system; they are asked if they would use a similar system to:

1. Conduct real-life negotiations;
2. Prepare for a real-life negotiation; or
3. Practice and improve their negotiation skills.

Over 75% of Inspire users stated that they would use a system like Inspire in real-life negotiations and over 85% would use such a system to prepare themselves to conduct actual negotiations [22]. The high level of user acceptance led us to conclude that a system like Inspire could be accepted in e-business negotiations.

2.3 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 [29, 30]. 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 [19, 31].

Software agents that 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 [15, 16, 32, 33]. Despite the claims made by the NSA developers, the use of negotiation methodologies is often oversimplified 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, 15, 34].

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 [16]. 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 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, and then provide a comparison of situations, interests and issues of past problems against the current problem [35]. 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 [36].

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 co-operate 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.

2.4 Complementary systems

Negotiating software agents (NSA) should not be discussed with the focus solely on the agents' abilities and behaviour. 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 however, 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 and also independently conduct 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.

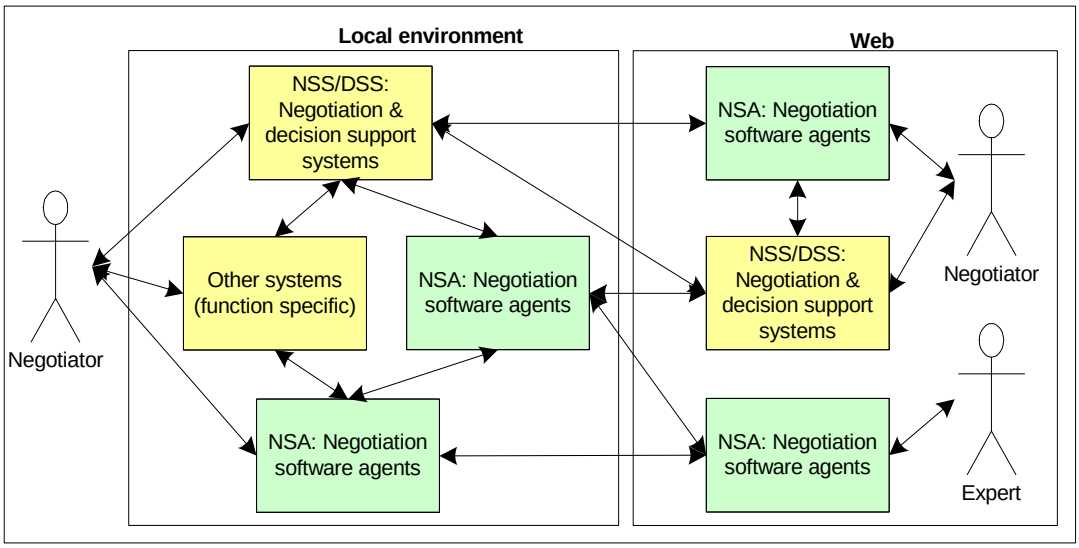

Figure 2. Configuration of complementary systems

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 [37] 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' may 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. Another important function of the agent is the provision of unbiased advice which may allow negotiators to reflect on their strategy and tactic. 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 [22]. The agents can, as indicated in Figure 2, request information from other agents, from experts and decision and negotiation support systems.

3. Aspire

3.1 Aspire framework

The Aspire system is an integration of Inspire—an existing NSS and Atin—an NSA. The main reason for linking Atin with the Inspire system is to provide the Inspire user with context-dependent support about the use of the system and advice regarding the negotiation process, and the user's and his/her counter-part's tactics and strategies.

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 continuously monitor the negotiation process so that it can provide a full range of methodological support, including the assessment of the user's activity, suggestion of possible strategies, tactics and offers, assessment of the counterpart's actions, and answers to the user's questions. The activities and tasks undertaken by Inspire and Atin in each phase of the negotiation are presented in Figure 3.

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 a number of the predefined paths of interactions.

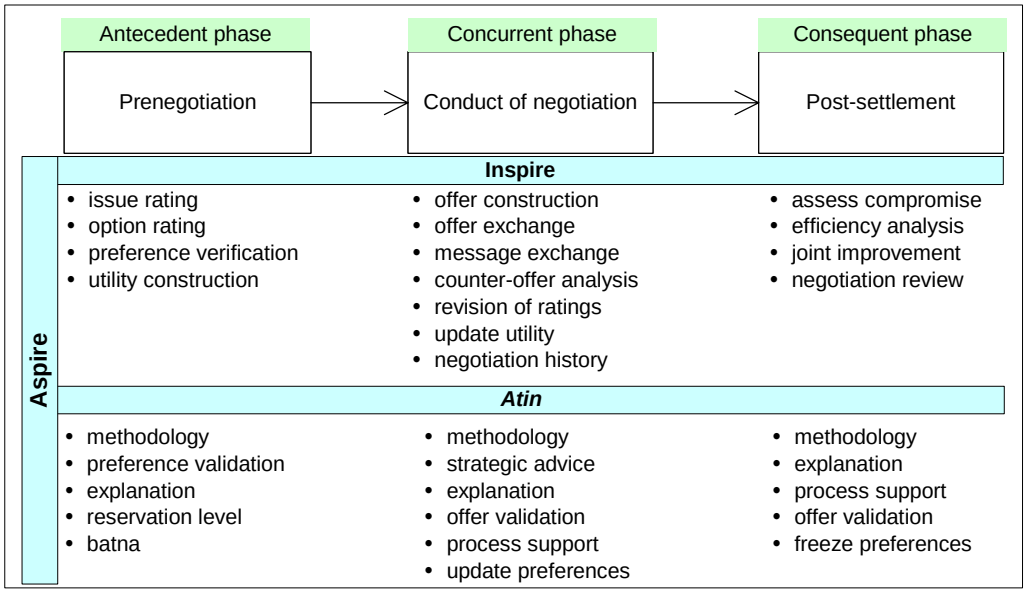

Figure 3. Aspire's support in the three negotiation phases

3.2 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 [38], including the Web client, the http server, the application server (consists of the NSS and the 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 a replacement of Inspire with a different NSS, and addition of additional NSAs, and for changing the scope of NSAs activities 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.

3.3 The functionality of Atin

During the preparation phase, Atin assists the negotiator in structuring the decision 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.

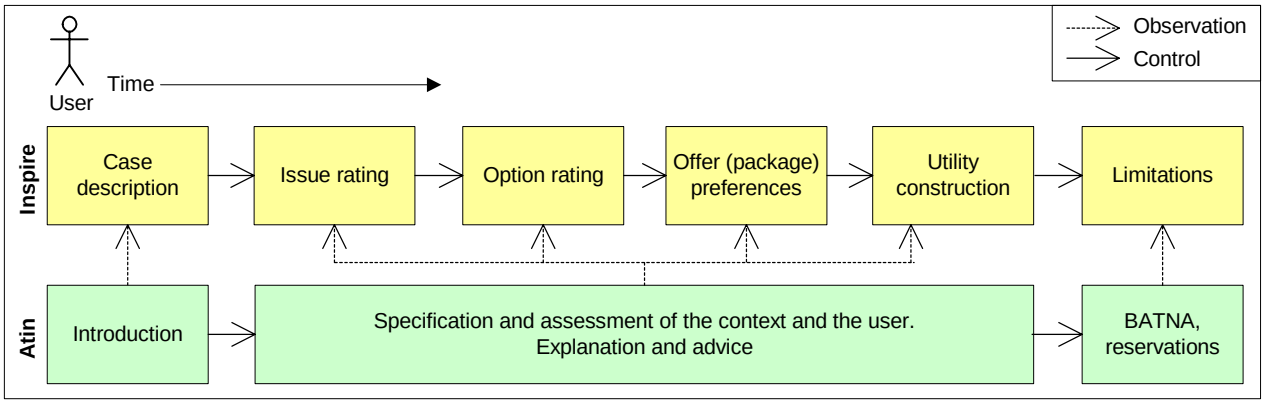

Figure 4. Support of Aspire in the pre-negotiation

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 makes a comparative evaluation of several complete packages selected by the system. The agent checks the knowledge bases and informs the user, if there are any violations of the predefined 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.

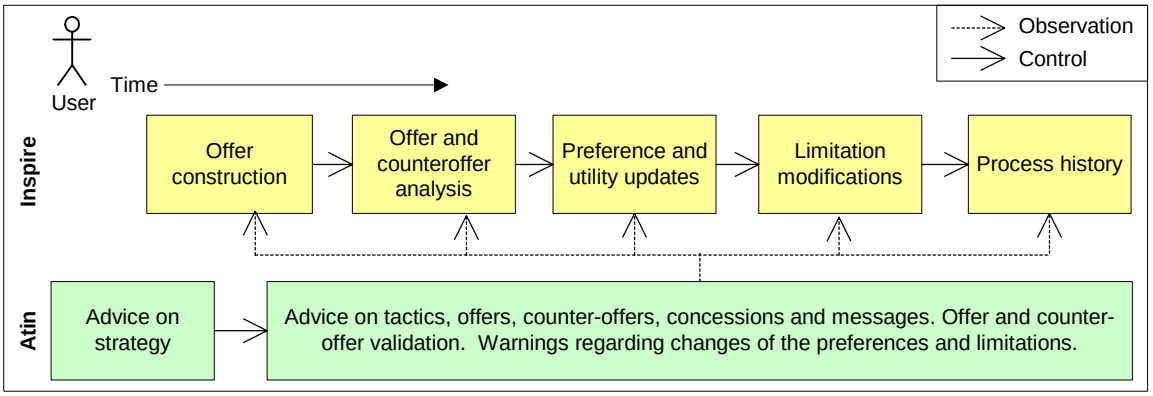

Figure 5. Support of Aspire in the conduct of negotiation

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.

Once a compromise has been achieved during the negotiation phase, the Inspire system retrieves utility functions of both users and verifies the compromise efficiency (Pareto-optimality). If the compromise is inefficient, up to five efficient alternatives that dominate the compromise are constructed and presented to both users. Users evaluate the efficient alternatives and may decide to continue the negotiation thus entering the post-settlement phase.

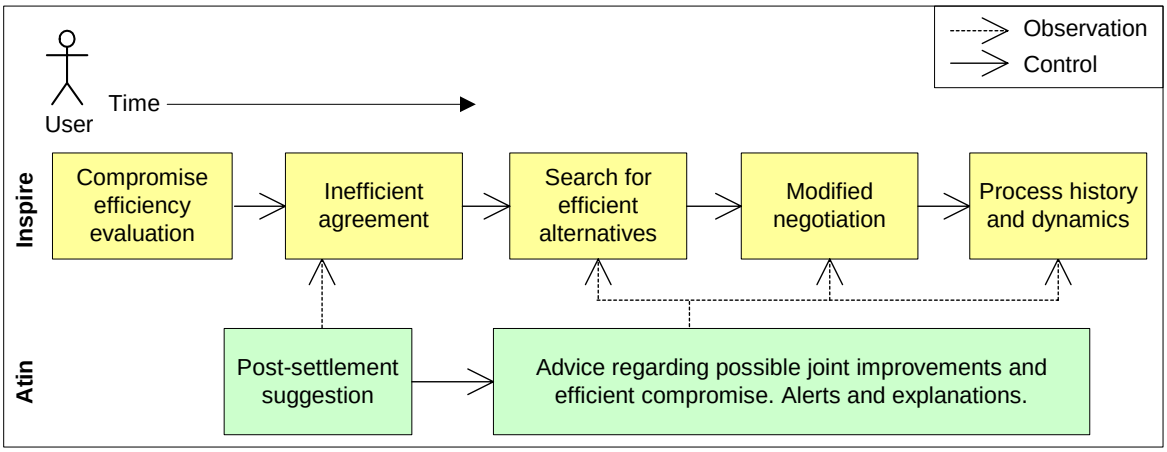

Figure 6. Support of Aspire in the post-settlement activities

There are many reasons why users may not be willing to attempt improving the compromise, for example, lack of time, other negotiations that require their attention, or improvement that appear small and irrelevant. It is also possible that users do not understand the improvement opportunity or do not wish to risk possible negotiation failure due in the post-settlement phase. In order to help users make an informed choice the agent provides an explanation of why the user may want to seek an efficient compromise and suggests that the negotiation continue. If both parties agree to continue the negotiation, Atin continues to support the negotiator providing advice similar to the negotiation phase.

The activities of Inspire and Atin during the post-settlement phase are presented in Figure 6.

4. Design and implementation

4.1 Aspire and Atin design

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 system are based on [18].

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 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.

The negotiation support component of Aspire, that is Inspire, has been developed with early Internet technologies and it does not use application and database servers. In the Atin agent we used a database server (MySQL). This required conversion of data obtained from Inspire to the database. The data conversion tool and other key components of Aspire are shown in Figure 7.

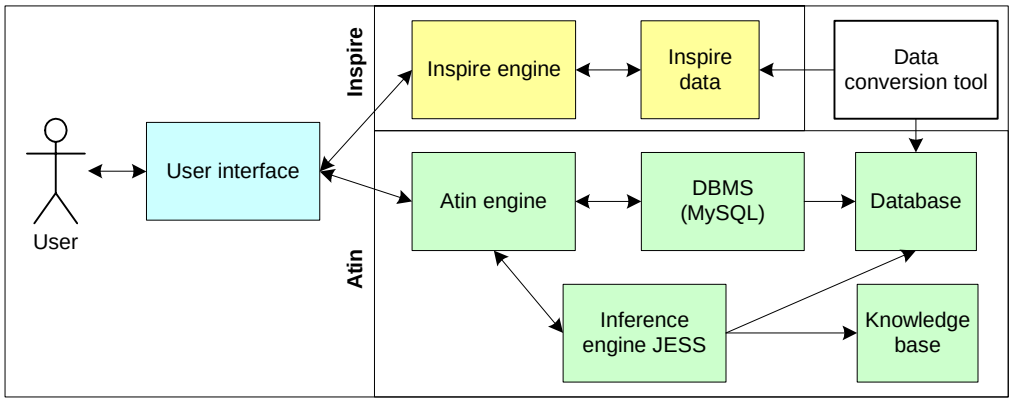

Figure 7. High level design of Aspire

Inspire has been discussed elsewhere [18], therefore in Figure 7 its main processing component (Inspire engine) and the data obtained from the negotiations and questionnaires are indicated. Atin has three main components: DBMS, inference engine and Atin's engine. The inference engine is JESS a knowledge-based shell written in Java (http://herzberg.ca.sandia.gov/jess/). The Atin's engine, written

in PHP and C++, extracts data from the MySQL database, invokes JESS and prepares information for passing to, or requesting from, the user. We should note that this implementation has been used to test the Aspire and the role of Atin; it is using a middleware layer (data conversion tool) because of the Inspire legacy problems.

4.2 Interface and user-system interaction

The interface of Atin 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 on the client side. 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 8. The three negotiation phases and main steps in each phase that the user needs to follow are presented in the Inspire component. A small window on the right introduces Atin and its functions. In order to make the agent unobtrusive the user may close the window or request additional information. The user may also disable Atin so that the communication window is not displayed; the agent, however, continues to be active so that the user is able to request advice and assessment at any moment of the negotiation.

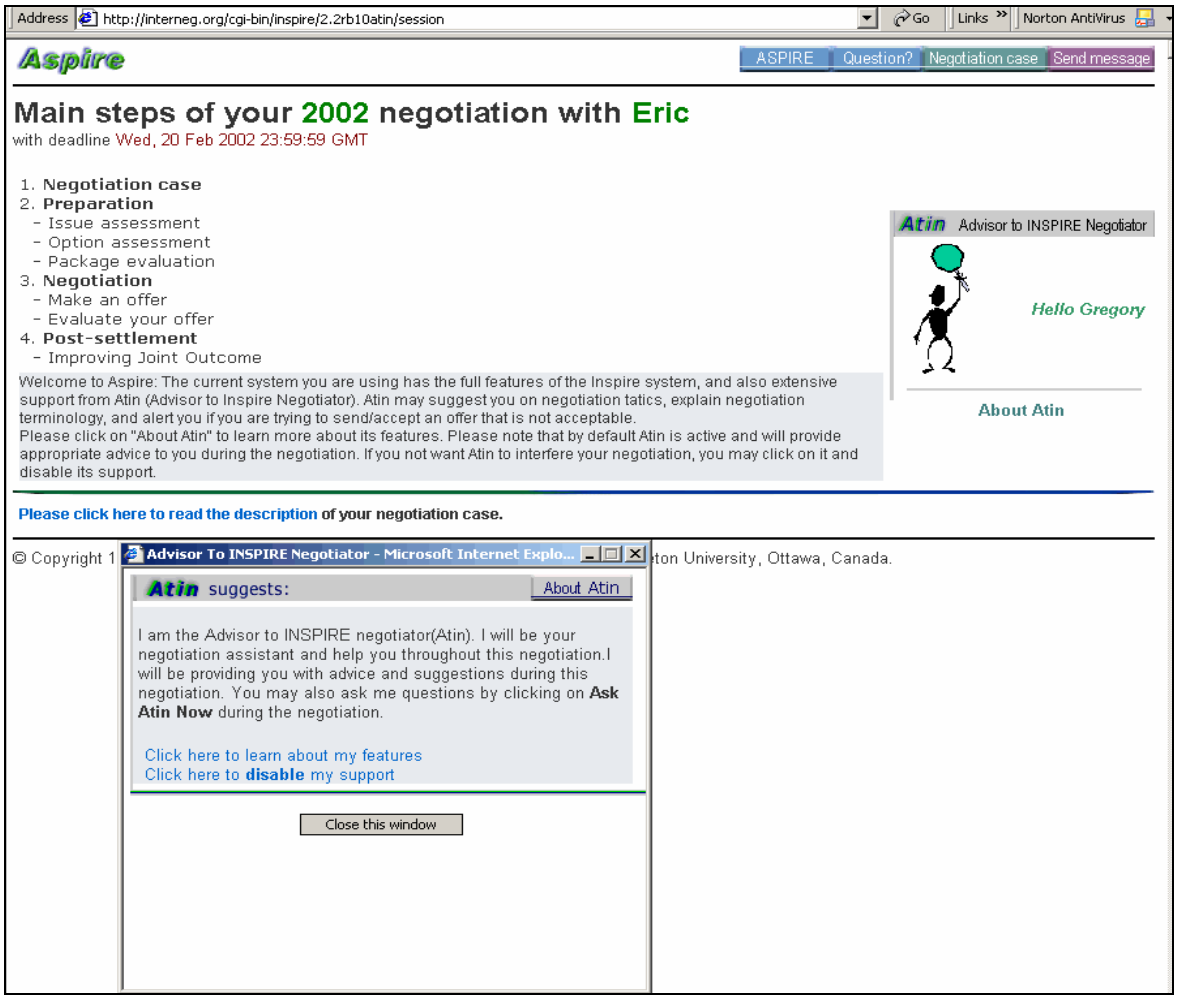

Figure 8. Two opening windows of Aspire.

Atin uses simple road signs to provide the user with its general assessment of the current situation. A green sign (shown in Figure 8) indicates that there is no warning, yellow indicates a warning, and a red sign (shown in Figure 9) 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 of past activities and for advice regarding possible moves.

An example of the suggestion made by Atin in the situation when the user violates one of the issue ratings rules is presented in Figure 9. In the negotiation case the user (Gregory) represents a firm (Itex) and he is given information regarding this firm's preference directions. For example the interest of the supplier is to obtain higher rather than lower price and more rather then less time to deliver the product. Figure 8 illustrates the situation when the Gregory disregards the firm's price preferences and assigns the highest weight to the lowest price. This prompts the agent to display a red sign. Subsequently Gregory opens Atin's window (in the lower right-hand corner) in which reasons for the display of the red sign and suggestion for a remedy are given.

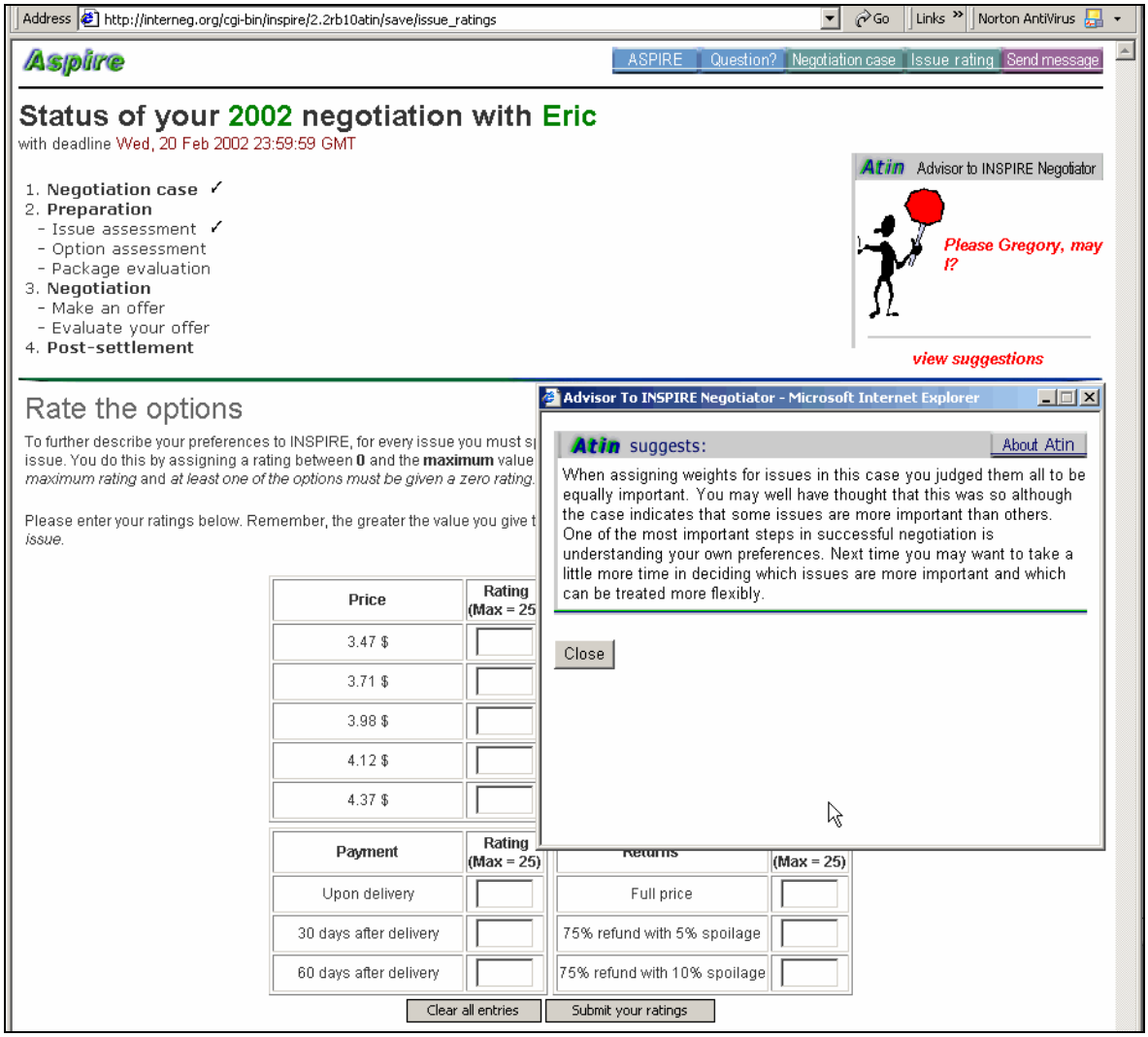

Figure 9. An example of Atin's advice in pre-negotiation phase

The user may ask Atin for advice regarding possible strategies. The agent displays a list of strategies

together with explanations about their positive and negative aspects. Atin's suggestion to Gordon, who negotiates with Gregory, is presented in Figure 10. This suggestion is based on Gordon's earlier decision to negotiate using hard positional bargaining strategy and his request for a possible opening offer. Based on this strategy requirement Atin presents an extreme offer (the most favourable to Gordon) and suggests that Gordon appends a message supporting this offer. Atin also proposed the structure of the message and its main arguments.

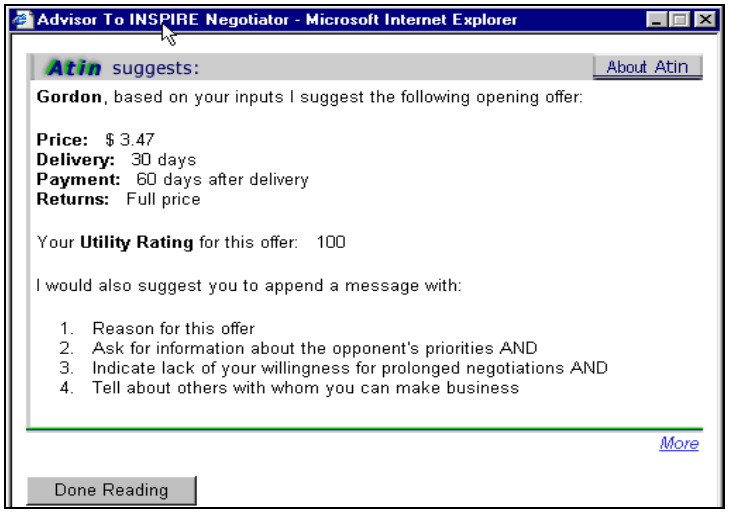

Figure 10. Atin suggests an opening offer

During the negotiation, users may change their strategy or a tactic without having sufficient reasons and they may undertake an activity that contradicts earlier selected strategy. One example of such an activity is making a significant concession under hard positional bargaining strategy. This situation is illustrated in Figure 11. Gordon selected an offer which yields utility value significantly lower than the utility value of his previous offer. This prompts Atin to ask the user to reconsider the offer before it is sent to Gregory, his counter-part.

Gordon may follow advice made by the agent or he may choose to ignore it. In the latter the user is prompted to confirm his/her decision. Such a prompt is presented in Figure 11. Because Gordon decided to submit the offer yielding large concession Atin requests confirmation.

5. User evaluation

In Section 1 we mentioned that proposing an agent-NSS environment and testing its contribution to support quality and user control as compared with an NSS comprise the second objective of this study. We used a well known Web-based NSS system and added a software agent knowing that the result inherits the legacy solutions of the NSS. The rationale was to verify if a software agent can add to the usability of an NSS, increase the user perception of being in control, quality of support and ease of use. The assessment thus concentrated on the users' assessment of the Aspire system and their experience rather than a rigorous verification of its contribution to the effectiveness and/or efficiency increase of the negotiations supported with an NSS+NSA environment as opposed to those supported with an NSS.

The Aspire system was tested with two groups of users each comprising 16 students. The first group

has used the original Inspire system within the last 12 months. The second group has never used a Inspire or another Web-based negotiation support system. Both groups were graduate and fourth year undergraduate business students. They all have similar computer skills and did not previously use a NSS (except for the group that used Inspire).

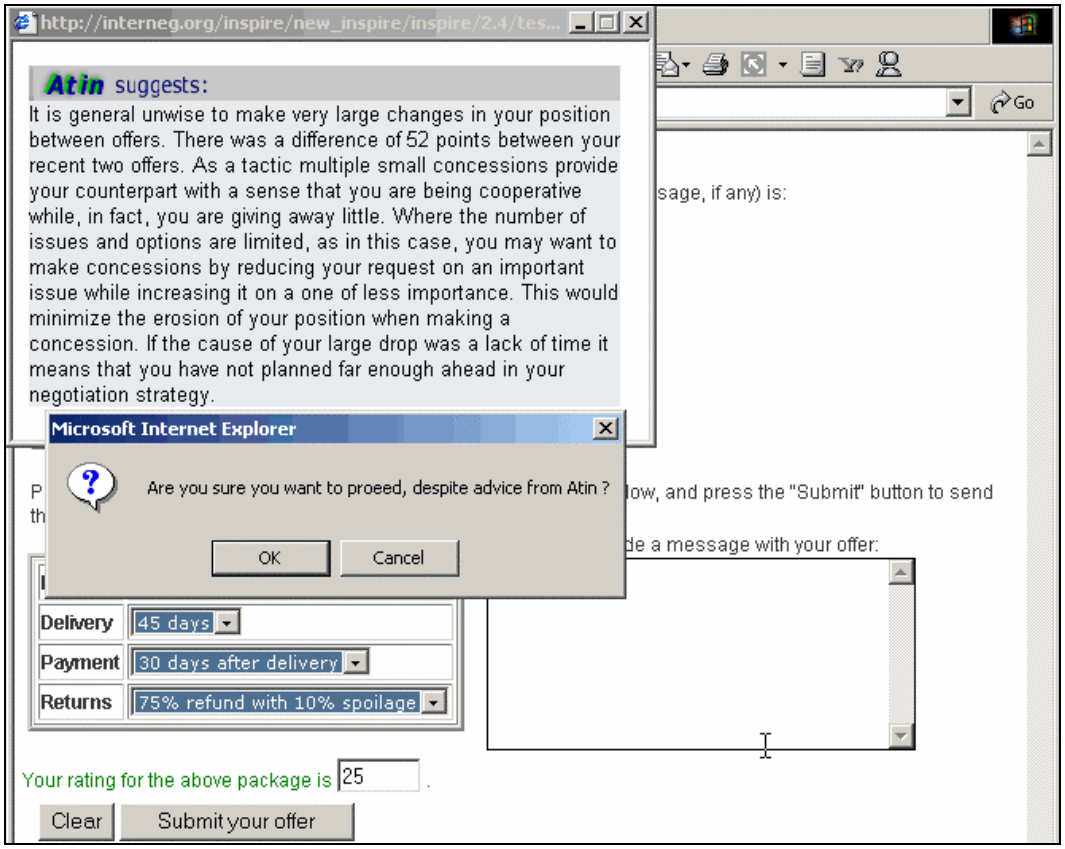

Figure 11. Atin's alert on large concession.

The same case of bilateral business negotiations was set up for the users from both groups. In each negotiation one user played the role of a buyer and another of seller. In each group users were randomly paired with each other. This arrangement was selected so that we can obtain feedback from previous Inspire users as well as 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.

The purpose of these questions was to obtain qualitative information about users perceptions regarding their being in control of the negotiations and the support process, the scope and level of support, and

the ease of the system's use. These are the key issues in providing decision and negotiation support to those who make decisions rather than experts and analysts. At this stage we concentrated on these issues rather than addressing the negotiation process efficacy and the quality of its outcomes. A positive initial assessment warrants further development and the conduct of formal experiments.

The testing proved that, due to the narrow bandwidth of some users, an applet knowledge-based system, as we have implemented using JESS, needs to be replaced with a more efficient solution (e.g., a server-based distributed knowledge-based system). 37% of Aspire users complained about the time to download the applet; this despite the fact that all users were from Canada. Since Aspire will be used by a similar population of users as the Inspire users, the system timely responsiveness is a critical issue.

The implementation of Atin highlighted the legacy problems with Inspire including the necessity to convert Inspire data from html-type files to a MySQL database developed for Atin. However, information collected by Atin could not be easily used by the Inspire engine even if it was relevant for negotiation support. This is because Inspire creates and uses several html-type data files which are difficult to augment with new information. Finally, the knowledge base we constructed is not complete and a significant effort is required to extract and unify the prescriptions and rules proposed in the negotiation literature. Notwithstanding these shortcomings of this version of the Aspire system, the testing of this version allowed us to test initial user perception and compare user attitude to Inspire and Aspire.

The overall feedback from the users was favourable. For people who have used the Inspire system before, 87% found that the Aspire system provided more support and it was much easier to use compared to the original Inspire system. This confirms our expectation that Web-based negotiation becomes easier with the aid of an agent.

The users were also asked in the survey whether they feel in control during the negotiation. 24 users, i.e., 75% of all users stated that they were in control of the negotiation process. All users who previously used Inspire noted that Atin assists the negotiation without taking over the control from them. Again, this confirms our expectations: an agent can provide support and advice to the user whenever required, but it does not take over the control of the negotiation.

We were interested in users' perception of Atin adding value to the process and their requirements in that regard. Interestingly, 25% of the users suggested a more structured process-type support. Examples of specific requests are to provide a "wizard-like" support to guide novice users through the negotiation process, and step-by-step instructions in how to define difficult constructs used in negotiations, including BATNA, aspiration levels and trade-offs values.

Majority of users from both groups (66%) stated 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 Aspire user made the following comment:

> "The pop-up warnings not only alert the user on an unreasonable action they have made, but also remind 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. The alerts also prevent me from overlooking important issues during the negotiation."

Users' evaluation of this version of Aspire proved that an NSS aided by an active software agent may add to the users experience, help better understand negotiation methodology, and make decision

grounded in this methodology. At the same time an active agent does not take control over the system and the negotiation. This implies that an NSA has a potential of acting as an advisor and/or expert to negotiation supported with an NSS. While further testing is required, in particular to assess the implication for negotiation efficacy, this means that negotiators may benefit from the proposed environment and use an NSS themselves rather then having it used by an intermediary analyst or expert.

6. Discussion

E-negotiation systems are used to automate the negotiation process with the use of software agents. This approach can be very useful in processes involving well-structured problems and where human learning and discover, and socialization and attempts to build business or other relationships are not an issue. Ill-structured problems that take shape and have issues clarified during the negotiation require human intervention. DSSs and NSS have been proposed to support such negotiations. In the past they were used by analysts and experts rather than negotiators themselves. Internet technologies allow many current and potential negotiators to access and use DSS and NSS.

The experiences with Inspire, users' suggestions, and the evaluation of the existing NSA led us to consider integration of NSS and NSA in a single software environment. In that we augment and extend research on the design and use of knowledge-based systems in negotiations [39, 40], with the work on decision and negotiation support that concentrates on problem structuring and analytical forms of support [3, 11, 18, 41], and with the work on the use of software agents to automate some or all negotiation activities [8, 15, 32]. We know of no other computing environment that integrates these three directions that has been implemented and tested.

The architecture of the proposed 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 the 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. Following the extension of Atin's knowledge base and the revision of the Inspire system we will conduct a larger study to compare the differences in negotiation effectiveness and efficiency between the users of Inspire and Aspire.

The next version of the agent will emphasise knowledge base development and the 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. This requires redesign of the Inspire system so that it and Atin, and also other software agents, can share the same database. We also plan to experiments with different Atin interfaces and its interaction with the users. This includes the evaluation of the necessity confirmatory inputs (see. Figure 11), the agent's intrusiveness, and presentation of its advice at different levels of detail.

The explosive growth in electronic commerce has not reduced the complexity of negotiations con-

ducted 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 a 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 match-making 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 too 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 which allows for human-system-agent interactions. Such an integrated architecture allows utilizing the strengths and capabilities of the methods and models which are embedded in the support systems and software agents. It also allows to better define roles of the individual components, the collaboration patterns, and the scope and levels of the agents' autonomy and the systems support.

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