Decision Support in Electronic Negotiation Systems - New challenges

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Abstract

Electronic negotiations can involve complex communication and decision processes if complex goods or service are involved. In such cases, an electronic negotiation support system (NSS) extended by a decision support (DS) component can provide valuable help for the users. However, since users have a bounded rationality, such complex processes will never be strictly linear nor rational. Therefore, there are a number of challenges that a DS method to be integrated into an NSS has to meet. This paper discusses the challenges and evaluates different methods for preference elicitation with respect to these challenges.

Keywords

Negotiation Support Systems, Decision Support, Preference Elicitation, Bounded Rationality

1. INTRODUCTION

Kersten et al. (1991) define a negotiation as a special form of decision and this view is typical in the area of negotiation analysis and negotiation support. Although valuable, the decision view is a strong simplification of real world dynamics.

First, we will provide a different process-oriented view on business negotiations. We will then give a brief review of past research on multiattributive utility theory in electronic negotiation support in Section 2. Section 3 explores the meaning of the process view for the implementation of such features in negotiation support systems (NSS) and identifies challenges, especially concerning the elicitation of preferences. This work is part of a larger effort on the integration of decision theoretical and communication theoretical views in the area of negotiation support technology. Section 4 then assesses established methods of preference elicitation with respect to the challenges identified. One important measurement will be the cognitive complexity. A summary will provide a comparative evaluation of the different alternative methods and will discuss the direction of future research (section 5).

A business transaction consists of three main phases, namely *searching* for potential business partners, *negotiating* about contract conditions and finalising the business contract, and *fulfilling* the contract. Negotiation in traditional as well as in electronic commerce is a complex communication process. Negotiation can be understood as an exchange of messages between multiple parties as well as the joint development of a document representing a contract version (Schoop, Quix 2001). Business-to-business negotiation processes can further be described as a path in three-dimensional space (Pohl, 1993). There is an agreement-, a specification- and a representation-dimension.

First of all, a negotiation process can be associated with a degree of *agreement* at a given time. Any negotiation aims at a complete agreement on the issues discussed, but may also end without an agreement.

The issues discussed may also change during the process. Any negotiation process is initiated by an offer or a request. These are not necessarily full *specifications* of a possible agreement. New issues are often introduced during the negotiation process, as the parties communicate with each other and learn. Thus, a negotiation process can be associated with a degree of specification at a given time. It should be noted, that the completeness of a contract specification only indicates a certain state chosen by the negotiators – Williamson (1985) points out that contracts evolve even after formal contract documents are signed. It is one of the basic insights of New Institutional Economics that formal contracts cannot be complete in a strict sense.

Finally, a business-to-business negotiation is meant to lead to a formal and legally binding contract between the parties, while the negotiation itself might be carried out using natural language. Therefore, a negotiation process moves in what can be seen as a dimension of *representation*. It should be mentioned that the three-dimensional path is not necessarily monotonic. Based on this understanding of a negotiation process, the goal of NSS can then be characterised as supporting negotiating parties in order to efficiently reach a completely and formally specified agreement. This can be achieved by supporting communication, document management and decision making in negotiations. The latter has the longest tradition.

2. EXISTING APPROACHES OF DECISION ANALYSIS IN ELECTRONIC NEGOTIATION SUPPORT SYSTEMS

Decision analysis and especially multiattributive utility theory (MAUT) play an important role for the support of electronic negotiations. NSS like Negotiation Assistant (Rangaswamy, Shell 1997), Inspire (Kersten, Noronha 1999), and SmartSettle (Thiessen, Soberg 2003) apply decision-theoretic approaches. Bichler (1999) considers decision analysis to have been a critical enabler for multi-attribute auctions.

Agent-based based approaches to negotiation support such as Tête-à-Tête (Guttman, Maes 1998) also rely on multiattributive decision theoretic approaches. MAUT can be applied for multiple purposes in NSS. First, it can be applied in its original sense as a tool for decision makers to explicate and discuss their preferences and identify possible trade-offs, which helps avoiding emotional decision biases (Rangaswamy, Shell 1997).

The second application of MAUT that comes into mind considering electronic negotiations is to elicit preference information from all negotiators and use it to identify pareto efficient outcomes. In the Negotiation Assistant and Inspire systems, a similar approach is used to identify joint gains in a post-settlement phase. This approach requires a trusted third party with access to both party's preferences, which leads to certain problems of acceptance. The Persuader system as proposed by Sycara (1992) had the even more ambitious goal to act as a mediator in order to facilitate problem solving during negotiations based on MAUT and case-based reasoning.

In general, it is desirable to estimate an opponent's preferences, i.e. his or her utility function, which is also a possible application of MAUT in negotiations. Further, estimated utility functions can be used to evaluate offers. This provides the negotiators with an orientation for the development and assessment of multi-attribute offers. This can be very valuable in complex, long-term negotiations or negotiations with many participants and is a prerequisite for winner-determination in multi-attribute auctions. The Inspire system employs this mechanism to visualise the utility development of offers over time as an indicator of the opponent's strategy.

In order to delegate a negotiation process to an automated agent, the agent must be parameterised with the decision maker's preferences. However, the elicitation of decision maker's preferences is a bottleneck in all of these application scenarios.

In the next section, it will be analysed how existing methods of preference elicitation that could be used as a basis for integrating decision support into electronic negotiation support systems face up to the specific challenges of such a support, if the process view of negotiations is assumed. Here, a prescriptive perspective is taken in an instrumental manner, i.e. it is investigated how to aid decision makers in specific situations, without imposing too many constraints or rules on them (normatively) while taking into account descriptive decision theory like the works of Simon (1957). The final decision will remain with the human negotiators.

3. SPECIFIC CHALLENGES OF INTEGRATED DECISION SUPPORT IN NEGOTIATION SUPPORT SYSTEMS

It has been discussed that complex negotiations that occur in traditional commerce require a complex form of negotiation support if to be conducted electronically. Thus, automated approaches alone cannot provide a solution. Rather, the idea of negotiation support is to retain the flexibility required for a complex process while offering support to help the negotiators find effective outcomes.

For example, the communication process could be structured to avoid ambiguity of exchanges; offers could be rated according to given preferences; a particular strategy could be suggested. In order to enable decision support by systems such as Inspire, Negoisst, or WebNS, these systems have to meet challenges that a complex negotiation processes poses. The following sections will introduce and discuss such challenges; the discussion will pave the way for an assessment of alternative methods for preference elicitation that will be presented in section 4.

3.1 Limits of preference elicitation

Preference modelling has a long history dating back to the discussion of expected utility by von Neumann and Morgenstern (1944) and faces, among others, the so-called problem of *observability* ever since: Preferences are difficult to measure. Methods that try to facilitate rationality in decision making in a negotiation regularly require full knowledge of the utility function of the entity affected by a decision. Simon introduced the concept of bounded rationality and thereby declared cognitive capacity a scarce resource:

> *"Rationality requires a complete knowledge and anticipation of the consequences that will follow on each choice. In fact, knowledge of consequences is always fragmentary. Since these consequences lie in the future, imagination must supply the lack of experienced feeling in attaching value to them. But values can only be imperfectly anticipated."*
>
> *(Simon, 1957, p. 81)*

The need for decision and negotiation support stems from problem complexity and ill-structuredness of problems. Thus, in many cases, the task of acquiring preferences is difficult or not feasible due to the size of the outcome space and the complexity of the utility elicitation process (Chajewska, Koller, et al. 2000). Further, preference-based methods are meant to be transparent and understandable for decision makers and to reduce their workload to a minimum at the same time.

There is obviously a trade-off relationship between the workload and benefits due to preference elicitation and DSS. While the cost structure in electronic commerce has dramatically expanded the potential of dynamic pricing mechanisms and negotiation, the cost of preference elicitation from individuals and/or businesses remains a serious bottleneck. This bottleneck can be operationalised, in a natural extension of the idea of rationality as a scarce resource, by introducing a cost of preference elicitation like in Parkes, Sunderam (2002) and Larson, Sandholm (2001). These costs can be operationalised as the computational complexity of a preference elicitation mechanism.

3.2 Changing preferences

The traditional premise of decision maker's rationality includes the fact that the decision maker considers all contingencies and their probability distributions in his/her decision. Under this assumption, a decision maker's preferences are obvious and stable. This is no longer true if only bounded rationality is assumed. Von Wright (1972) stresses that it is not possible to speak about preferences ignoring that these are preferences of a specific actor at a specific time. In particular in complex principal agent negotiations with a strong information asymmetry, it can be expected that principals acquire new information and discover new contingencies during the negotiation process. As Clyman and Tripp (2000) put it: What a negotiator cares about at the start of a negotiation might not be what that negotiator cares about at the end of the negotiation.

This leads to a rationally required change of the preferences in a DSS. Thus, decision support in electronic negotiation systems must be prepared for changes in decision maker's preferences and minimise decision maker's effort for changes.

3.3 Incremental preference elicitation of new issues

In classical negotiation analysis it is assumed that 'all inventing and creating of issues' has occurred before the parties actually start negotiating (Keeney, Raiffa 1991). Using the same argumentation that leads to changing preferences of decision makers, it is obvious that the structure of the issues under negotiation is likely to change as well in real life negotiations:

> *"Rationality requires a choice among all possible alternative behaviours. In actual behaviour, only a very few of these possible alternatives ever come to mind."*
>
> *(Simon, 1957, p. 81)*

Negotiators acquire new information and discover new alternatives during a negotiation. This might lead to the need of discussing additional issues not considered before. Decision support in NSS will have to support such situations. However, a change in the decision problem's structure should lead to minimal effort for decision makers and partial preference information might be reused.

3.4 Partial Information in the negotiation process

As already described, negotiation is an iterative process in which an increasing level of specification is intended. Electronic negotiation is done by the exchange of messages (Schoop et al., 2003; Weigand et al. 2003) which cover only parts of the later agreement. This has different reasons. One reason is that new issues arise during the negotiation as covered in section 3.3. Another reason is that, although issues are known from the start people first concentrate on the most important issues or have other strategic rationales (see e.g. Shaheen et al. 2003). Further, bounded rationality might be a reason not to negotiate about all issues at the same time in complex scenarios.

Thus, if offers have to be rated by a DSS then the DSS needs to be able to give a rating even if there are some issues to which no value has yet been assigned. It is not possible to give an exact rating value for an offer with partial information but it is possible to give a range of the possible ratings with only the known values fixed: each unspecified attribute is set to the value which was rated with the highest and lowest satisfaction value respectively to simulate worst-case and best-case scenarios. This can give a basic understanding of a particular offer's effect on overall utility and the 'room to negotiate' that is left.

This functionality puts two constraints on preference elicitation. Firstly, the method used must yield a numerical (i.e. additive) preference model (Keeney, Raiffa 1976, p. 91) in order to evaluate 'new' alternatives. Secondly, the method must allow utility estimations after an initial preference elicitation and not after a learning period. All the methods of preference elicitation that will be discussed in the next chapter are based on the additive model and thus fulfil this requirement.

3.5 Ambiguity in Natural Language Communication

The ambiguity in human speech is a very basic problem for the provision of DSS features in electronic negotiation systems (Schoop et al., 2003). As long as there is no agreement on the meaning of the terms negotiated, utility estimations are worthless, because it is unclear what is actually evaluated. On the other hand, vagueness is a valuable mechanism of complexity reduction in human communication and can indeed be a conscious choice of communicative behaviour in negotiation processes.

This problem calls for a dedicated communication support and i.e. the support of negotiations of ontologies or the integration of certain standards into free text negotiations. There are currently research activities in this area (e.g. Schoop and Jertila, 2004; www.sewasie.org). However, the problem is far from solved. We will have to assume that all negotiators come to a common understanding of the issues to negotiate during the process and update their preferences accordingly, if the understanding of an issue changes.

4. EVALUATION OF SELECTED METHODS OF PREFERENCE ELICITATION

Different approaches for the reduction of cognitive load in preference elicitation have evolved, e.g. the AHP and Conjoint Analysis approaches discussed below. Only recently incremental approaches have been proposed, where software elicits partial preference information as needed and rates the preferences known so far (Conen, Sandholm 2001).

In the following subsections, selected preference elicitation methods will be analysed regarding their cognitive complexity. Complexity Theory is part of the theory of computation dealing with the resources required during computation to solve a given problem. The resource requirements of algorithms, i.e. methods in our case, are expressed as a function of the problem size n. In our case, let n denote the number of attributes to be considered in a negotiation. As decision support for complex negotiations is desired, n is assumed to be comparatively large (20+). Where necessary we will assume 3 possible values for each attribute. The basic operation used as a cost measure is a single evaluation judgement or comparison performed by a decision maker in a preference elicitation process. For each method, we have three different algorithmic problems to consider: initial preference elicitation, changes of preferences, and adding attributes.

4.1 Self explicated approach to preference elicitation

The simplest way of acquiring preference information is asking for it directly. Each attribute and attribute level of possible alternatives is judged explicitly and separately while interdependencies between attributes are assumed to be insignificant. Decision makers evaluate the levels of each attribute, e.g. on a 0-100% desirability scale (assuming other attributes to be constant) and then weight the attributes' importance by allocating e.g. 100 percentage points across them. Although questionable from the perspective of descriptive decision theory, this self-explicated approach is not necessarily inferior to e.g. conjoint techniques in terms of validity (Sattler, Hensel-Börner 2000; Srinivasan, Park 1997). However, ratings might also be biased because decision makers are either not able or not willing to fit their preferences into this schema.

Self-explicated preference elicitation is transparent to decision makers and advantageous in terms of cognitive effort (Srinivasan, Park 1997), which obviously increases linearly with the number of attributes and levels, without any scaling factors: $\Theta(n)$.

Changing preferences and adding attributes is unproblematic with a self-explicated approach as all attributes can be rated separately, which allows decision makers to edit their preferences as needed. All other preference information can be reused. In case of a change of importance ratio between two attributes, decision makers have to change their judgement of importance explicitly for those two attributes in order to preserve a constant sum. This is an operation with constant cognitive complexity: $\Theta(2)$.

If a new issue is introduced into the preference structure, its importance must be explicated while the importance of all other attributes can be rescaled automatically in order to preserve a constant sum. However, this implies that the ratio of importance between all attributes already known remains unchanged: $\Theta(1)$.

4.2 Conjoint measurement approaches

Conjoint measurement is a set of methods for the identification of preferences in multi-attribute decision making. Simplified 'buying' decisions are simulated in order to derive preference information in a second decompositional step. It was introduced as a method of mathematical psychology in 1964 (Luce, Turkey 1964) and later applied in marketing research (Green, Rao 1971). An additive, compensatory preference model and the independency of attributes are usually assumed. Conjoint techniques are widely and successfully used in consumer research. However, conjoint techniques suffer from not dealing well with inconsistent data and being boring for the decision maker. Therefore, Guttman and Maes (1998) question conjoint techniques as the sole mechanism for extracting preferences for integrative negotiations in retail electronic commerce.

Regarding the cognitive complexity of conjoint methods, consumer research showed that classical full profile conjoint analysis, even if implemented with fractional factorial designs, is limited to five or six attributes in order to prevent an information overload of decision makers and to ensure the validity of results (Green, Srinivasan 1978; Srinivasan, Park 1997). With this limitation, more complex decision problems can only be addressed by 'bridging' multiple studies (Green, Srinivasan 1978). Assuming 3 attribute levels per attribute in an orthogonal design commonly created with SPSS (18 items in this case), we can estimate the worst case computational complexity of the decision maker's problem as follows. The basic task in full profile conjoint is sorting and we assume that decision makers rely on simple sorting algorithms like insertion sort, which is known to be a member of the $\Theta(n^2)$ complexity class. Using 6 attributes in each bridged study where 1 of them is occupied for the bridging yields $\Theta((18^2\ n)/5)$ as a worst case estimation, which is in the linear complexity class.

A multitude of variations of conjoint analysis has been derived to overcome this limitation, including Hybrid Conjoint models (Green 1984; Srinivasan, Park 1997) employed in the Inspire system. The basic idea is to enrich a self explicated approach with a decompositional step in order to overcome the limitations and biases of self-explication and to preserve its simplicity: decision makers rate a fixed or comparatively low number of stimuli and this information is used for a correction of the utility values explicated by a decision maker. The cognitive complexity of this method is thus equal to the self-explicated approach with an additional constant value.

The changing of previously elicited preferences is not covered in the conjoint measurement literature. In a classical and possibly bridged full profile setting, changing preferences implies reconsidering all ordering decisions made, i.e. repeating the whole elicitation or the bridged part respectively. If we assume that as a basic operation the importance of two attributes changes, then only one bridged part has to be reconsidered. Hence the cognitive complexity of the change of preference is constant in $\Theta(18^2)$. In a hybrid conjoint approach, however, preference values are visible to decision makers and thus can easily be edited (see self explicated approach). Another benefit of the Hybrid approach is the visibility of the utility values to the decision maker – using a traditional Full Profile Conjoint for preference changes is inadequate, because the decision maker has no direct control over the utility function and the changes made to it.

As the conjoint measurement literature is mainly concerned with consumer research, dynamic changes of the problem structure are not considered. However, the introduction of additional attributes is feasible with all conjoint approaches. In full profile approaches new attributes can be included by 'bridging' a new measurement to previous measurements, which leads to $\Theta(18^2)$ basic decision operations to update the preference information. Hybrid conjoint approaches benefit from the flexibility of the self-explicated approach, which treats attributes more separately. Thus, there is little to no repetition of evaluation tasks necessary as data can be reused, if we assume that the preference relations of all attributes previously known does not change by introducing a new attribute.

4.3 Analytic Hierarchy Process (AHP)

The Analytic Hierarchy Process (Saaty 1994) deals with structuring a decision problem by a hierarchy of goals or criteria and a simple rating method based on this structure. The rating is based on the additive model.

The first step is to build the hierarchy starting with a main goal and defining subcriteria successively. For each stage it is then necessary to get the preferences for the criteria. This is done by making pair-wise comparisons. A comparison is done by asking how much more important criterion a is than criterion b. The possible values are usually restricted to the set 1,3,5,7,9 and the compromise values 2,4,6,8. If the number of subcriteria of one criterion is n, then n(n-1)/2 comparisons will be necessary. If the comparisons are consistent (which means that for example if a is 3 times as important as b and b 3 times as c then a is 9 times as important as c) then only n-1 judgements have to be made, because the others can be derived. This is often not possible due to the restrictions on the ratio values. The comparisons are represented in a matrix like this:

	Goal 1	Goal 2	Goal 3
Goal 1	W1/W1	W1/W2	W1/W3
Goal 2	W2/W1	W2/W2	W2/W3
Goal 3	W3/W1	W3/W2	W3/W3

Table 1: Example of an AHP matrix

Here W_i/W_j is a weight ratio. For each subcriterion an additional matrix is needed. On the last stage the matrix has the aim to rate alternatives with respect to the subcriterion. An alternative is a set of values representing a complete stimulus. For each of the criteria of the last stage of the hierarchy there is one value in the alternative.

One Problem of AHP is the ranking reversal problem (Saaty 1994; von Nitzsch 1998). If there are two possible actions or alternatives a and b and a has the higher ranking value it is possible that the ordering of a and b changes when a third alternative is included without changing the pair-wise comparison values for a and b. This problem is solvable by using a standardisation by bandwidth and not by sums. Another problem is the bandwidth effect (von Nitzsch 1998). The importance of criteria is rated without regarding the bandwidth of the values that the alternatives can have.

If the decision problem is complex, this can result in a large number of stages in the hierarchy. Consequently there are many matrices, which have to be filled in (for each node in the hierarchy, one matrix is needed). Especially if the matrices are not consistent and attributes can not be ordered hierarchically, the amount of comparisons for the user increases quickly. In the worst case, i.e. if only a single matrix is used because no hierarchy could be defined, the cognitive complexity of the preference elicitation is $\Theta(1/2n^2\text{-}n)$.

A change of preferences can be made on each stage by changing some of the pair comparisons directly: $\Theta(1)$. If there are fundamental changes then more than one matrix is affected.

If a new criterion is introduced then at least one new matrix has to be introduced if it has no subcriteria. In addition, the matrix of the upper criterion has to be extended with the comparisons of the old with the new criterion (adding one column and row to it). There, at least one comparison is needed (consistent matrix) and at most it has to be compared to all other attributes in the matrix. Assuming the single matrix case, introducing a new attribute will therefore yield a complexity of $\Theta(n\text{-}1)$.

5. CONCLUSIONS AND SUMMARY

In this paper we positioned decision support in NSS and reviewed applications of Multiattributive Utility Theory in existing systems. Further, we derived five challenges to the design of decision support systems integrated with NSS by omitting the rationality assumption of classical Negotiation Analysis: The general limitations of preference elicitation due to problem complexity, the dynamics of preferences, the dynamics of the problem structure itself and its understanding, and the necessity for integrated DSSs to deal with issue-by-issue negotiations.

The role of preference elicitation as a bottleneck becomes clearer with regard to these challenges. In a next step, selected approaches of preference elicitation were evaluated according to their computational complexity with respect to human cognition as a ‘scarce resource’. Table 2 summarises the results.

Elicitation method	Scaling for many attributes	Changing preferences	New issues
Self Explicated Approach	$\Theta(n)$	$\Theta(2)$	$\Theta(1)$
Full profile conjoint	$\Theta((18^2\ n)/5)$	$\Theta(18^2)$	$\Theta(18^2)$
Hybrid Conjoint	$\Theta(n) + c$	$\Theta(2) + c$	$\Theta(1) + c$
Analytical Hierarchy Process	$\Theta(1/2n^2\text{-}n)$	$\Theta(1)$	$\Theta(n\text{-}1)$

Table 2: Summarised worst case effort approximation of preference elicitation methods in negotiation support

However, to choose a preference elicitation approach in any meaningful way, the internal validity of the approaches (i.e. the degree to which the insights of descriptive decision theory are taken into account) has to be considered as well in this trade-off decision.

Here the Hybrid Conjoint group of approaches is perceived as the most beneficial alternative with regard to the new challenges identified above. Surprisingly, this choice is consistent with those already made e.g. in the development of Inspire and Negotiation Assistant, although both systems rely on classical, normative Decision Theory. Both systems use Hybrid Conjoint Measurement as a preference elicitation mechanism.

The results of the present study are limited because all mechanisms are evaluated as groups of approaches while a multitude of methodological questions remain untouched (scaling, stimulus presentation etc.; cf. Green 1984). Further and especially empirical research is required in this area, investigating the performance of other forms of preference elicitation and decision support mechanisms in NSS. Future research should empirically verify the role of the challenges identified and compare concrete instances of methods. Then a mode of integration with communication support features must be found.

Our practical research focuses on the Negoisst system (Schoop et al. 2003) since it provides communication and document management support and offers flexible and yet effective support of complex electronic negotiations. The system structures the negotiation (communication) process based on the theory of speech acts and by an annotation of natural language messages representing a semantic enrichment process. We then integrated a decision support component into the hitherto communication-oriented Negoisst system. The DSS component will mainly provide utility estimations for the semi-structured messages.

The integration enables an empirical investigation of the major challenge in NSS design: finding the right balance between the structure of negotiation protocols and decision models on one hand and the need for simplicity and flexibility on the other hand.

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