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Interactive Multiple-Criteria Methods for Reaching Pareto Optimal Agreements in Negotiations

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Abstract

The common features of two interactive methods that can be used in multiple-party negotiations over continuous issues are studied. One method is based on finding jointly improving directions to the parties to move along and the other on making constraint proposals to the parties. The history and the related literature on the subject is briefly surveyed in order to position the methods within the field. The basic similarities and differences together with the possibility to use them jointly are studied from the point of view of single negotiation text concept. Potential application areas including facilitation agents in distributed artificial intelligence are suggested.

Key words: interactive methods, multiple-criteria methods, negotiation analysis, post-settlement settlement procedure, single negotiation text procedure

1. Introduction

In a negotiation process there are at least five main phases or activities where mathematical modeling can provide prescriptive decision aid; for details see Kersten (1997). We briefly discuss these phases, and the factors in them that are important to position the two methods that we shall consider in this paper within the field.

First is the search for the arena and selection of the communication mode. In this phase the negotiating parties, the location for the negotiation process together with the communication mode to be used are specified. These items can be either physical or virtual. This phase also includes the specification for the use and exchange of information and for the use of experts and mediators.

Second and third phases are agenda setting, and exploring the field, respectively. These phases constitute the structuring of the problem. The joint terminology to be used and the issues and the decision alternatives to be decided upon are discussed and agreed. The discussion is based on the parties' possibly different interests that can be described by appropriate decision criteria and operational measurable attributes. The parties establish limits to the decision alternatives, aspiration levels to specific criteria, and formulate their best alternatives to a negotiated agreement (BATNA; a term introduced by Fisher and Ury 1981). Analytical methods and simulation can be used to assess the implications of certain decision alternatives together with the possible process evolution. Computer-based support has a significant role in these studies. A general framework to model the second and third phases is the evolutionary systems design framework for negotiation modeling (ESD; see Bui and

Shakun 1996; Shakun 1988, 1996. For a full application of the framework see Hämäläinen et al. 2001).

It should be noted that in axiomatic bargaining theory, a descriptive game theoretic approach to bargaining originated by John Nash (1950), agenda setting only means the order in which issues in multiple issue bargaining will be considered (for a general presentation on axiomatic bargaining see Myerson 1997). The order will affect the properties of the resulting bargaining solution. The bargaining solution is also affected by the timing of implementation of agreements on individual issues; Fershtman (1990), Ponsati and Watson (1997). In prescriptive approach to negotiation modeling, i.e., in negotiation analysis, it is often assumed that the agreement is not implemented until agreement on every issue is available.

The fourth phase is narrowing the differences and search for integration. Knowledge about Pareto optimal solutions, the search for them may have started already in the previous phase, is refined through an intensive exchange of information. The parties learn their own and each others' potential to reach a compromise and can assess its main features. Also identification of the key issues and those alternatives which may lead to disagreement are identified. Analysis of negotiation may focus on the selection of negotiation strategies, e.g., concession making or joint problem solving, and of selection of initial positions in negotiation, e.g., joint or separate position. The choice of a negotiation strategy may further lead to the restriction of Pareto optimal outcomes to those acceptable to all parties. The tasks in this phase can be supported by methods based on multiple-criteria decision making (MCDM) and multiattribute utility theory (MAUT); see, e.g., Hämäläinen et al. (2001).

The fifth phase is search for agreement and improvements. A limited number of compromise outcomes is produced and identified and one of these is chosen as the final compromise. If the settlement is not Pareto optimal there are still joint gains left to be produced to all parties. For this task analytical methods based on single negotiation text (SNT; a concept introduced by R. Fisher for Camp David negotiations in 1978. See Fisher and Ury 1981; Raiffa 1982) and post-settlement settlement (PSS; a concept introduced by Raiffa 1982) are available.

In this paper we shall study the common features of two well-known, interactive iterative negotiation support methods developed by the authors in a series of earlier papers. So far the methods have been discussed separately and these features, although contributing to their possible joint use, have not been considered. The methods can be used to support negotiations in a variety of ways; in particular in the last two phases mentioned above. They can be implemented as user-friendly computer systems that would act as mediating devices assisting the parties directly or assisting a mediator in a joint problem solving situation. There are two main uses for the methods. One is the development of the Pareto frontier with the negotiation then becoming distributive along the frontier. This can be done by running the methods from different, systematically varied initial alternatives. Another is to use the methods in the PSS fashion from a given non Pareto optimal tentative settlement to create further joint gains and the final settlement to the negotiations.

We will discuss the possibility to operate the methods together in SNT-type negotiations for step-by-step creation of joint gains from a well defined starting SNT. We will also discuss the essential features of SNT mediation from the point of view of a well defined interactive mathematical programming framework. This is done in section 5. In fact, based on Raiffa's (1982) verbal description of the SNT procedure (see section 2.2) we shall argue that one of the methods, the method of improving directions, formalizes SNT procedure mathematically. We will also give a new interpretation for the other method, the constraint proposal method, in terms of hierarchical MCDM in large scale systems. The two methods are presented in sections 3 and 4; other related analytical approaches to negotiation support are briefly discussed in section 2. In section 6 we discuss practical aspects of one of the methods in the light of role playing experiments. In the conclusion section we briefly argue that in addition to "traditional" negotiation aid suitable application areas for the methods can be found within the field of distributed artificial intelligence and electronic commerce.

2. Background and associated methods

2.1. Analytical negotiation support methods

Teich, H. Wallenius, and J. Wallenius (1994) give an extensive and thorough literature review on negotiation science. They divide the analytical negotiation support methods into four modeling categories:

(a) value function based methods/interactive methods
(b) concession based methods/joint gains seeking methods.

Thus we may roughly speak about four different types of methods depending on whether the parties value functions are explicitly constructed or not, and whether the parties take a joint problem solving attitude to negotiation or not. Nevertheless, it is often difficult to classify different methods so sharply; rather they are mixtures of these extreme types. In concession based methods the parties start negotiations from separate positions whereas in joint gains seeking methods the parties start from a jointly accepted position. Often various methods also include items from axiomatic bargaining models that are descriptive in nature and are better to predict the solution of a particular bargaining situation than in aiding the parties to achieve it. This approach will be needed, e.g., in a further development of the method of improving directions; see section 5.

Raiffa (1982) shows how to systematically construct an additive value function to all parties. Taking the weighted sum of the individual value functions and maximizing the sum with various weights results in the development of the parties' Pareto frontier. After that the parties may select the final outcome making, for example, concessions along the frontier. An alternative is to use an adjustment process on the Pareto frontier based on a suitably chosen "axiomatic" bargaining solution. For example, an adjustment algorithm developed by Raith and Welzel (1998) shows that the Adjusted-Winner procedure of Brams and Taylor (1996) in fact implements the Kalai-Smorodinsky (1975) bargaining solution. Ehtamo, et al. (1989) use iterative methods in a same vein along the Pareto frontier to obtain Nash- (1950) and Kalai-Smorodinsky bargaining solutions. There are only few applications based on Raiffas' (1982) theory; see, however, Mumpower (1988) and Sebenius (1983). This is because even in the additive case the parties' value functions are not very easy to elicit.

Raiffa (1982) has also presented some ideas how joint gains could be produced in the SNT spirit; he doesn't, however, go beyond the value function based methods in his analysis.

There is a large number of various interactive concession based MCDM methods together with the applications based on these; for details see Teich, H. Wallenius, and J. Wallenius (1994). Especially see the papers by Kersten (1995), Korhonen and Wallenius (1990), and Korhonen et al. (1979).

A promising amount of literature is also dealing with interactive joint gains seeking methods. In an early paper by Korhonen et al. (1986) an attempt is made to identify joint gains for a group of parties by asking pairwise comparison questions from a group as a whole. Another method based on nonlinear programming was presented by Bronisz et al. (1988), where the parties set aspiration levels to the criteria to move to the jointly preferred directions. Other interactive joint gains seeking methods include the RAMONA-method developed by Kuula (1990, 1998), and Teich et al. (1995), and the constraint proposal methods developed by Ehtamo et al. (1999). Constraint proposal methods, the RAMONA-method being a special case of these, are discussed in detail in section 4.

SNT-type joint gains seeking procedures have been studied by Ehtamo et al. (2001), Ehtamo et al. (1992, 1999), Korhonen et al. (1995), and Teich et al. (1996). In the first two papers the joint gains producing directions are chosen heuristically by asking pairwise comparison questions from the parties. In the latter three papers a well defined interactive method based on mathematical programming is developed for SNT-type mediation. Our discussion in the rest of the paper will mainly concern SNT-type mediation.

We finally remark that the informational requirements and working ways of SNT and concession based methods are very different: Under SNT all parties work under the guidance of one system and provide it with the information it requires whereas in concession based mediation every party may work under his own system.

2.2. SNT-mediation

SNT, or the one text procedure as it is called by its inventors Roger Fisher and William Ury (1981) is a special case of the method of principled negotiation developed under the leadership of these authors at the Harvard Negotiation Project. In short the message of principled negotiation is that (Fisher and Ury 1981, page xii):

> . . . you look for mutual gains wherever possible, and that where your interests conflict, you should insist that the result be based on some fair standards independent of the will of either side.

The method emphasizes the importance of the joint problem solving aspect in negotiations for, as Fisher and Ury put it (Fisher and Ury 1981, page 11):

. . . the participants should come to see themselves as working side by side, attacking the problem, not each other.

The SNT procedure was used by the United States acting in a mediator's role in the Middle East peace negotiations between Egypt and Israel at Camp David in September 1978. In these negotiations there were seven specific issues on the merits to be decided upon, and then there was a starting package made by the U.S. team putting some initial suggestive values to the issues. Raiffa (1982, chapter 14) gives an extensive description on the course of Camp David negotiations. According to him the U.S. team made it clear to the negotiating parties, Egypt and Israel, that it was not trying to push this first proposal, but that it was to serve as a starting one text, a single negotiation text SNT-1. This text was to be criticized by both parties, and then based on this criticism modified and remodified iteratively by the U.S. team until the text could be improved no more. The SNT was to be used as a means of putting the parties to work on the same problem, on the same composite text, although the parties were physically working separately.

Before letting the parties to criticize a new SNT they were asked if they preferred it to the previous one. In Raiffa's (1982) example SNT-5 can no more be improved for both parties at the same time so that it is Pareto optimal, by definition; see Figure 1. Nevertheless, Raiffa remarks that the number of SNTs in actual negotiations were not five but more likely twenty-five.

We continue this story in the next section where we argue that the SNT procedure described above can be formalized mathematically as an MCDM gradient search method.

3. The method of improving directions

Assume first that there are two issues A and B, say cost and time, at stake that take continuous values and assume that the ranges of the issues have been specified in advance. Let x_A and x_B denote the levels of the issues in SNT-1, denote $x = (x_A, x_B)$ and represent the SNTs on the coordinate plane. Ask now a party to criticize x. Perhaps the party lets you know that she would like more of both issues, or just more of issue A and less of issue B. In any case you should be able to say into what quadrant (imagine the origin and the coordinate axes translated at x) the party would like to move from x. Imagine that you draw a small circle centered at x and take some points on the circle in that quadrant. Asking from the party which one of these points does she prefer, you are able to draw an approximate gradient direction of the party's value function at x; namely by drawing a line segment from x through that point; see Figure 2. The more you take points on the circle, the better the approximation. For a concave value function we now know that moving a small step from x to any direction the angle with the gradient direction being strictly less than $\pi/2$ will increase the value function. Taking the intersection of the sets of improving directions for both parties gives us the set of all jointly improving directions. Finally, taking one such direction, e.g., the one bisecting the angle between the parties' gradient directions, and moving a suitable step to that direction gives us a point which we may call SNT-2.

In Ehtamo et al. (1992, 1999) it is shown that the method of improving directions will converge in a two party case provided proper conditions are met; for example, (a) the

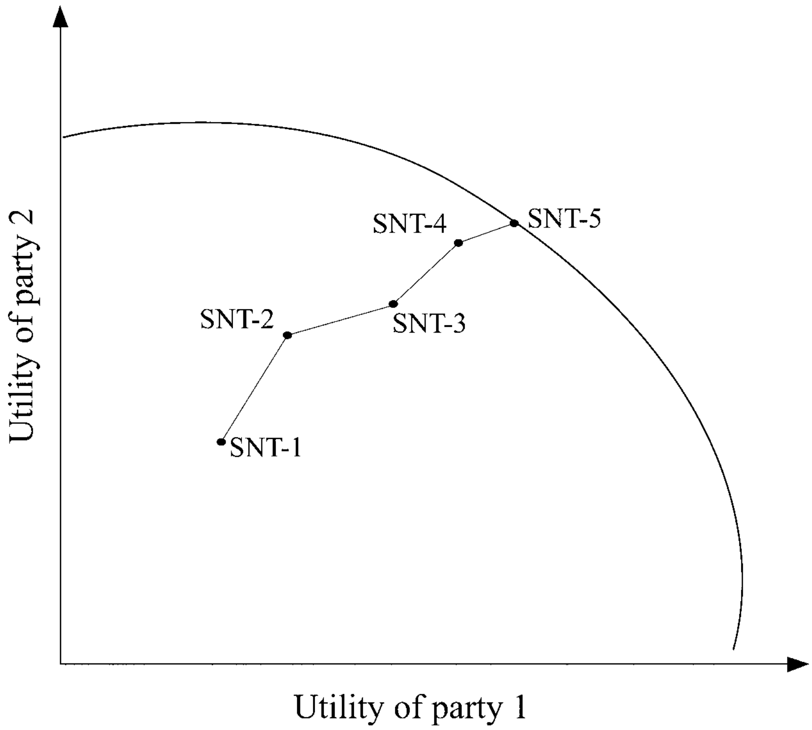

Figure 1. Seeking for joint gains produces successive SNTs.

gradient direction of the parties together with the final step, which is the minimum of the distances all the parties like to move along the chosen jointly improving direction, are exact, (b) the direction of move bisects the angle between the gradients (or, in general is a continuous function of the starting point), and (c) the produced SNTs remain strictly within the ranges of the issues.

In Ehtamo, Kettunen, and Hämäläinen (2001) the method is generalized to include many parties and many issues. The choice of the compromise direction is done by solving a maximin mathematical programming problem and the convergence issue is discussed, but not solved, in the case of both linear and nonlinear constraints. In particular, it is shown that the parties' gradient directions can be identified approximately by considering two-issue circles at a time keeping the other issues fixed to their SNT values. The search on the circles can be visualized on a computer screen either by asking the pairwise comparison questions among discrete points on the circle, or by scrolling a bar in which case all the alternatives on the circles can be viewed. That is exactly what the Joint Gains software (Kettunen et al. 1998) does; for user experiments with the software see section 6. Figures 3 and 4 illustrate the user interface visualization of the software for the two choice problems on the circle; i.e., one with discrete alternatives and the other with all points on the circle. In the figures cost (issue A) is assumed to be, e.g., in the units of millions of dollars

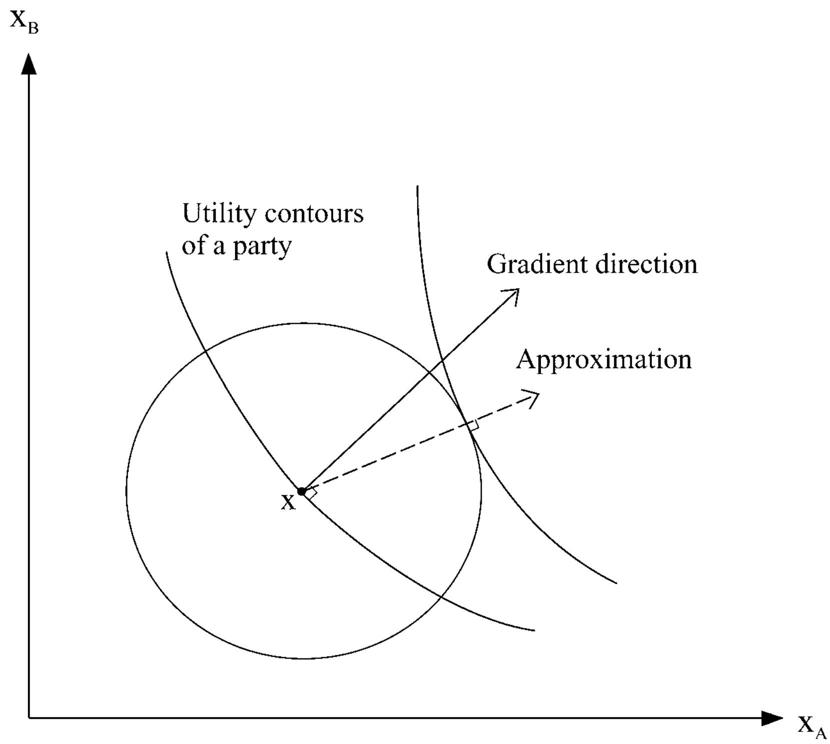

Figure 2. An exact and an approximate gradient direction of a party at x.

and time (issue B) in the units of days. The ranges for the issues vary from 0 to 4, and from 0 to 40, respectively. Along the circle the values of the issues (visualized by the pillars) vary around the current SNT, say (1.5,32).

4. The constraint proposal method

Constraint proposal methods are joint gains seeking methods provided the parties' underlying value functions are concave and differentiable. Under the present formulation the methods are not, however, SNT-type methods. In the next section we shall discuss the possibility to reformulate them to adapt to SNT-type mediations. To describe the methods suppose first that there are two parties negotiating over n continuous issues. Under the concavity and differentiability assumptions mentioned above there is a joint tangent, which is a line when $n = 2$, see Figure 5, and a hyperplane when $n > 2$, to the parties' value functions at any Pareto optimal point. So given a reference point $r = (r_1, \ldots, r_n)$, where r_i is a fixed level of the i:th issue, the methods try to locate the joint tangent going through r; the joint point of tangency being the resulting Pareto optimal point. There are several con-

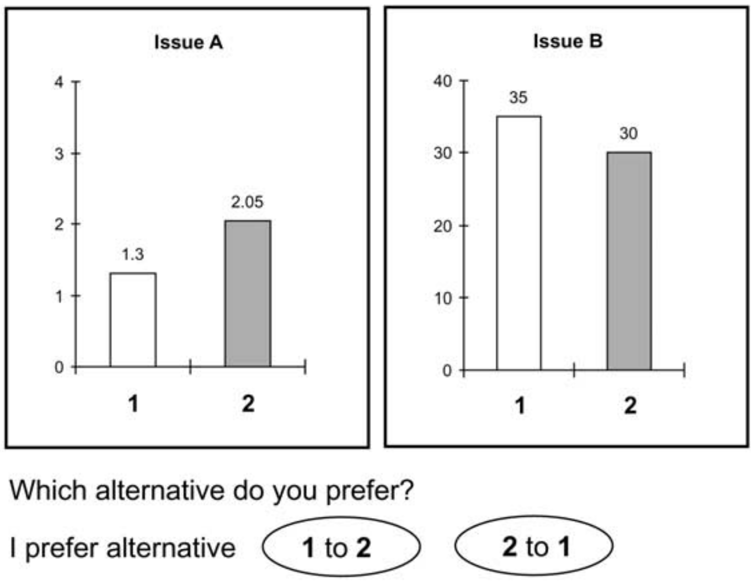

Figure 3. The party is asked to compare two alternatives on the circle at a time.

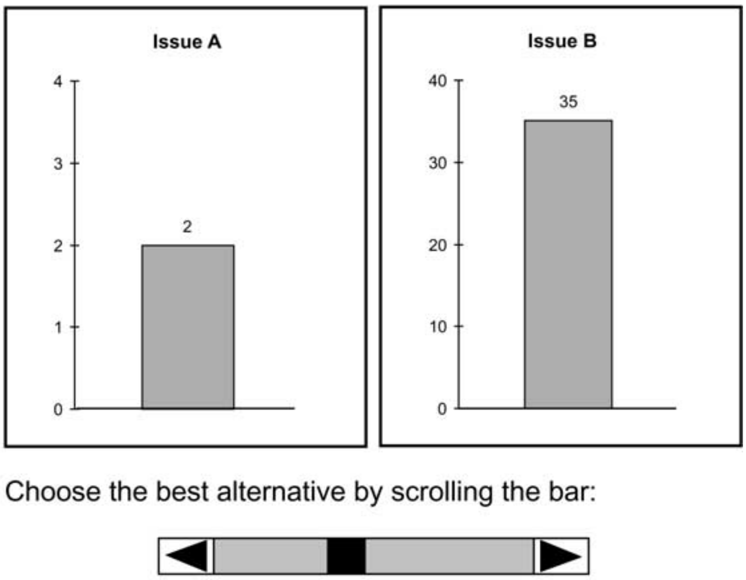

Figure 4. The party is asked to choose the best alternative on the circle by scrolling the bar.

venient iteration schemes for the adjustment of the tangent. Various iteration schemes correspond to various (constraint proposal) methods; see below.

Consider the two-issue case. Operated by a mediator the methods work as follows. The mediator chooses a reference point *r* and an arbitrary plane going through it. He announces the plane constraint to the parties who give their optimal alternatives on the plane; see Figure 6. From the point of view of the individual parties the problems they face are ordinary constrained optimization problems with an extra linear scalar constraint representing the equation of the hyperplane. Using the difference vector of the optimal alternatives the mediator tilts the hyperplane so that the iteration of the method diminishes the distance between the optimal alternatives. The iteration stops when the optimal alternatives coincide.

The theory, history and background of the methods have been presented in the article Ehtamo et al. (1999) for a two party many issue case. Ehtamo et al. (1992, 1996), and Verkama et al. (1996) used the idea of locating joint tangents in distributed computation of Pareto optimal solutions for games where there is one decision variable for each (possibly many) player, like in oligopoly games. Actually Osborne (1976) first gave a strategic interpretation for the joint tangent through the joint optimal point for the parties, or the oligopoly firms. He also raised the question of identifying this line under incomplete

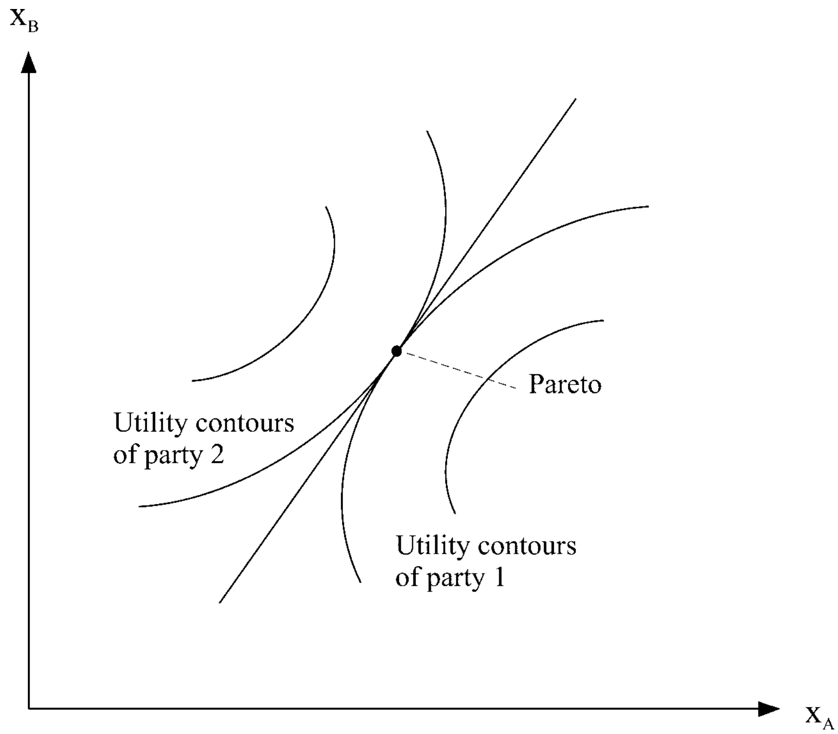

Figure 5. There is a joint tangent to the parties' value (utility) functions at a Pareto optimal point.

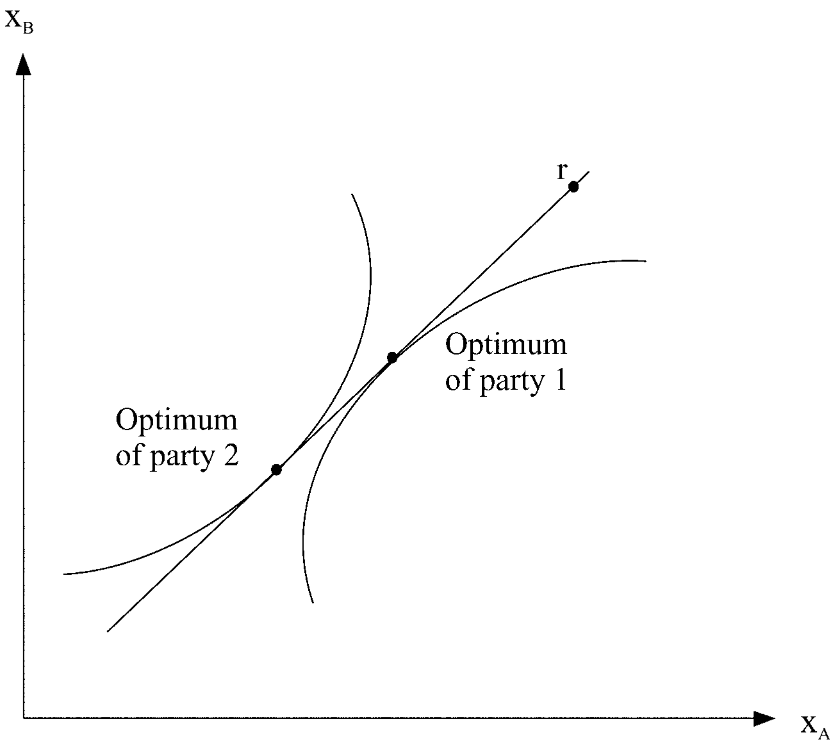

Figure 6. The parties give their optimal answers on the given line (hyperplane).

information about the firms' profit functions. This line can be used to define Nash equilibrium strategies for the cartel members to support the jointly optimal production. The idea has been further generalized in a dynamic resource management game by Ehtamo and Hämäläinen (1993, 1995). Teich (1991), and Teich et al. (1995) develop heuristics called RAMONA based on the Slutsky equations in microeconomic theory (see, e.g., Varian 1992) for the tilting of the hyperplane in a two party case. The RAMONA software (Kuula 1990, 1998) has been built on this heuristics. Other, more traditional iteration methods can be found in Ehtamo et al. (1999).

Constraint proposal methods can be used to produce a number of Pareto optimal points for a set of given reference points. The negotiation then becomes one of choosing a compromise from these points. Or they can be used in the PSS fashion to test the Pareto optimality of a negotiated settlement. The methods can also be generalized to handle more than two party cases; see Heiskanen et al. (2001). In the m-party case one iterates with $n - (m - 1)$ hyperplanes going through a fixed reference point.

Like the method of improving directions these methods can be generalized to include constraints as well (Heiskanen 1999b). Nevertheless, the convergences of the methods in the case of constraints has not yet been verified mathematically.

5. Joint use and further development

One way to interpret the constraint proposal methods is to see them as price coordination or nonfeasible methods in hierarchical MCDM of large scale systems. In optimization of large scale systems the objective is to find the overall Pareto optimal solution for the system; see Haimes et al. (1990). The solution of the original problem is decomposed into the solution of subproblems connected with each other by some coupling equations and some coordination variables. The coupling equations need not always have physical interpretation. In the well known case of microeconomic equilibrium analysis (Arrow and Debreu 1954) the coupling equation represents the resource constraint of an exchange economy. The coordination variables are usually either prices of the various resources or the Lagrange multipliers associated with the coupling equations; in the latter case they can be interpreted as shadow prices. Solving the subproblems with given coordination variables and updating these variables so that the coupling equations are finally satisfied solves the original problem. In constraint proposal methods the requirement that the parties' optimal solutions on the hyperplane coincide can be interpreted as a coupling equation and the normal vector of the hyperplane as a coordination variable. For an extension along this direction see Heiskanen (1999a).

One way to unify the method of improving directions and the constraint proposal methods is the following. Take SNT-1 as the first reference point and choose an arbitrary hyperplane constraint going through it. Then elicit the parties' gradient directions to produce SNT-2 just as in the method of improving directions, but now on the given plane. At the same time when the gradients are elicited, the mediator may ask the parties' optimal alternatives along their gradient directions. The next hyperplane is then chosen through the new reference point SNT-2, but with the new normal vector chosen in order to diminish the distance between the optimal alternatives on the gradients.

Suppose there are three issues at stake. With the "original" method of improving directions we must interactively perform a one-dimensional search through two circles in order to elicit the gradient for a party. With the new method we only need to search one circle because we are restricted to lie on the plane. Observe, however, that in order to tilt the next plane correctly we must have information on the party's best solution along her gradient direction, again a one-dimensional search. Thus the new method, although promising at the outset requires at least as many one-dimensional searches as the original one. Nevertheless, it seems that the number of total SNTs to be produced will diminish. These observations are currently under further study.

Mathematical programming gives a convenient modeling framework for the simulation and analysis of SNT-type mediation. The approach taken in Ehtamo et al. (2001), and in Ehtamo et al. (1992, 1999), is essentially the Zoutendijk's gradient search method (see e.g., Bazaraa et al. 1993) with the value function gradients elicited interactively. As such it is very similar to the interactive MCDM gradient search methods derived from the Geoffrion et al. (1972) method (see e.g., Yu 1985). The Zoutendijk's method allows an appropriate handling of the constraints defining the feasible set; yet the convergence properties of this method are not satisfactory and need further consideration.

The difference between the traditional single party gradient search methods and our multiple party method is that in the single party case one gradient determines the direction of move while we here have several gradients and in some way we must find a compromise between these directions. A convenient choice is the maximin direction that is also included in the Zoutendijk's original formulation (Zoutendijk 1960) where the gradients are those of the active constraints and the objective function. Besides maxmin direction other choices are also possible. Ehtamo, Verkama, and Hämäläinen (1999) present a fair way to choose the compromise direction in a two party case based on axiomatic bargaining theory (Myerson 1997). A generalization of this to the many party case is complicated and needs further research.

Elicitation of gradient directions is an essential but not an easy task in these methods. The underlying mathematics is simple but the software used by the mediator to visualize it to the parties should be carefully planned. A well known method (see e.g., Yu 1985) to approximate the parties' gradient directions is based on the elicitation of the value functions' contours in the vicinity of the current point. This amounts to the asking of indifference questions from the parties. The method presented by Ehtamo et al. (2001) on the other hand is based on searching the best alternative on a circle. This has led to the invention of scrolling the bar and pairwise questioning visualization interfaces used in the Joint Gains software; recall the discussion in section 3. There is also some encouraging experience on the use of these aids which we will discuss in the next section.

6. Role playing experiments

In the introduction we discussed the main phases that characterize various negotiation, or group decision and negotiation processes (see also Kersten 1997). In Hämäläinen et al. (2001) a unified multi-criteria framework for modeling and support of multi-stakeholder decision processes is described. The framework is applied to the development of a new water level management policy for a regulated lake-river system in Finland. The stakeholders are involved in the decision process from the beginning, problem structuring phase, to the end, group consensus seeking phase. The described overall process serves as a good example of the use of the ESD framework. Other examples of its use in the area of environmental problem solving include, e.g., Fukuyama et al. (1994), and Rajabi et al. (1997).

The method of improving directions was tested in student experiments in the fourth phase of the process for the seeking of Pareto optimal solutions. The aim of the role playing experiments was to test the operational feasibility and interactivity of the method and the user interface of the Joint Gains software (Kettunen et al. 1998). Here we state the most important observations made in these experiments. Similar observations were made in student experiments in the negotiation analysis course supervised by the authors in Systems Analysis Laboratory, Helsinki University of Technology, in spring 2001.

In the first experiment the students were divided into nine, two party groups. There were different roles for the parties representing various interest groups: environmentalist, summer resident, fisherman, farmer and power company. Before the experiment the students were familiarized with the case and the used decision criteria. Also the main objectives of each role were given. In this first experiment all two party groups were present in each of the nine two-party sessions and in every session one computer was running the Joint Gains software.

The parties found it easy to answer the stated questions both with the "scrolling the bar" and "pairwise questioning" interfaces. With both interfaces starting from the same initial alternative led to the same final point. This suggests that both devices are equal in the assessment of the most preferred alternative on the circle, provided of course that the parties are consistent in their preferences. Different starting alternatives led to different outcomes as is expected. This is an essential feature of our two methods which is easily shown to be true theoretically, see e.g., Ehtamo et al. (1999), and Teich et al. (1995). Therefore these methods can be used to generate an approximation to the Pareto frontier by applying the methods from different starting alternatives. That different starting positions lead to different outcomes in SNT-type negotiations was also noticed by Korhonen et al. (1995), and Teich et al. (1996) in simulation experiments.

In the second experiment there were three parallel sessions with all five roles represented in each session. The communication between the mediator and the five parties was distributed so that the parties could work privately with their own computers. In each session there was one computer running the Joint Gains mediator software and one computer for each party running the Joint Gains user interface. The computers communicated through a local area network.

Although the software itself proved to work well in both experiments, it was learned that more attention has to be paid to the instructions given to its users. Also clear understanding about the problem at hand would help the users in successful execution of the experiment. We also learned that it could be frustrating for the parties to react to tens of questions or bar scrolling requests without clearly understanding the current status of the negotiations, e.g., whether and what kind of progress had been made in the search so far. In real negotiations this thing could scarcely happen because there are different types of facilitators keeping the parties all the time well informed. In short: the experiments showed that the questioning methods in preference identification worked well, and that the work in producing even four or five Pareto optimal points is fairly reasonable. This is partly because only one or two SNTs are usually needed to capture almost all the joint gains available in a gradient search method. In Ehtamo et al. (2001) a preliminary numerical simulation experiment is performed about the effects of increasing the circle radius together with diminishing the number of comparison questions on the circle in order to, (a) make the compared alternatives as different as possible, and (b) still to obtain a reasonable accuracy in the final outcome. Elicitation methods based on these observations are currently under study.

7. Conclusion

We have focused on two interactive MCDM methods that can be used to aid parties in multiple issue negotiations. The theoretical development has taken place in several papers; yet the basic ideas appear already in Ehtamo et al. (1992). This paper is descriptive in nature and its approach is game theoretic, although interactivity and especially the mediator's role as an information collector are also emphasized. The method of improving directions, for example, is described as a "bargaining process involving two parties that take turns to make proposals under incomplete information." The proposals are possible compromise directions defined as tradeoffs between issues. In order to guarantee the convergence of the process it is assumed that the utility functions' gradient directions are known at the iteration points. Under reasonable assumptions this is sufficient information needed to have a convergent process.

In the game theoretic modeling of bargaining and negotiation the problems related to incomplete information have received a great deal of interest over the last two decades. These issues are considered difficult to solve and thus very challenging; see e.g., Sutton (1986). Incomplete information is the prevailing condition in markets and in decision making situations. In modeling it is sometimes taken into account, but more often it is ignored. Therefore it would be most valuable to find methods that can be used to produce Pareto optimal profits under such circumstances. In the SNT-type negotiations decisions are made under incomplete information in the game theory sense; only after some information about the parties' gradient directions is available the compromise direction choice problem can be approached with the methods based on axiomatic bargaining theory (see Ehtamo et al. 1999).

The evolution of internet technologies is most interesting for negotiation support. Now the parties need not come to one place but can easily participate from their own location anywhere in the world. Today there are a number of web-based applications available, see for example Kersten and Noronha (1999), and Kettunen et al. (1998). In the near future a web-based application area of significant interest will be agent mediated electronic (e-) commerce; see for example Guttman et al. (1998). Automatic software agents can be facilitators between the buyers and sellers. There can also be automatic agents with a well defined role and prespecified package of information representing, e.g., various consumer groups, seller groups, etc. They could automatically negotiate under a facilitator agent about such issues as warranties, delivery times, service contracts, return policies, loan options, gift services and other merchant services. When the agents' preferences are well defined mathematically there exists basis for negotiations of the joint gains type. In general, this kind of agent modeling has roots in distributed artificial intelligence (DAI). Verkama et al. (1992) remark that the type of methods we are focusing here are especially suitable to handle problems in DAI because of their ability to distribute the joint problem solving task to sub-tasks for autonomous agents.

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