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GROUP DECISION AND NEGOTIATION SUPPORT IN EVOLVING, NONSHARED INFORMATION CONTEXTS

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M.F. SHAKUN (*)

(*) New York University, Leonard N. Stern School of Business, Graduate Division, 100 Trinity Place, New York, New York 10006-1594. Travail réalisé dans le cadre d'un séjour au LAMSADE.

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L'AIDE A LA DECISION ET A LA NEGOCIATION DE GROUPE EN SITUATIONS EVOLUTIVES : LE CAS D'INFORMATIONS NON PARTAGEES

RESUME

A partir de la méthodologie "Evolutionary Systems Design" (1), on traite de l'aide à la décision et à la négociation en situations évolutives à acteurs multiples dans le cas d'informations non partagées.

Une situation d'informations non partagées - c'est-à-dire sans partage complet de l'information - est associée à ce qu'on appelle couramment une situation "non-coopérative" dans la littérature des SIAD.

Lorsqu'il n'y a pas de partage complet de l'information, on se trouve en présence du jeu à information incomplète de la théorie des jeux.

Ce jeu est, en général, évolutif.

On s'intéresse ici à la façon dont le SIAD MEDIATOR (2) peut contribuer à l'évolution de la représentation du problème de groupe. Il s'agit d'un processus de recherche de consensus par partage (ici partiel) d'information pouvant occasionner l'adaptation et la restructuration du problème et faire l'objet de compromis.

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(1) "Conception évolutive des systèmes évolutifs".

(2) Système Interactif d'Aide à la Décision et à la Négociation de Groupe.

GROUP DECISION AND NEGOTIATION SUPPORT IN EVOLVING, NONSHARED INFORMATION CONTEXTS

ABSTRACT

Based on evolutionary systems design (ESD), group decision and negotiation support in evolving, nonshared information contexts is discussed. A nonshared information context-one without full information sharing- is associated with what has been loosely called a "noncooperative" context in the group decision and negotiation support systems (GDNSS) literature. Without full information sharing, we have a game with incomplete information that, in general, is evolving. The paper discusses how the GDNSS, MEDIATOR, supports evolution of the group problem representation - a process of consensus seeking (through information sharing, here partial) subject to problem adaptation and restructuring within which compromise is possible.

Keywords : group decision, negotiation, evolving contexts, nonshared information, evolutionary systems design.

1. GROUP DECISION AND NEGOTIATION SUPPORT SYSTEMS: EVOLUTIONARY SYSTEMS DESIGN AND MEDIATOR

Group decision and negotiation support systems (GDNSS) provide decision support in problems involving multiple decision makers, thus extending decision support systems (DSS) for single decision-maker situations.

Shakun (1988) develops evolutionary systems design (ESD) as a methodology for problem definition and solution (design) in complex, self-organizing contexts involving multiplayer, multicriteria, ill-structured (evolving), dynamic problems. ESD is an artificial intelligence framework for GDNSS.

A central concept in ESD for GDNSS is the evolving group (coalition) problem representation based on the union of individual-player problem representations. An individual or group problem representation consists of relations between decisions or controls, goals, criteria and preferences; also a goals/values relation relating goals to values. Policy making may be viewed as the design of purposeful systems to deliver values to participants in the form of operational goals.

Implementation of this concept has been initiated in the GDNSS called MEDIATOR (Jarke, Jelassi and Shakun 1987). MEDIATOR is based on ESD and database-centered implementation.

1.1 Group Decision and Negotiation Setting Overview

Following ESD in Shakun (1988), a group of N players (who may change over time) is involved in a multiplayer decision problem (game). A subset of the set η of N players can cooperate and form a coalition C ($C \subseteq \eta$) which, at either extreme, can be η itself, the grand coalition, or an individual player. Coalition C may also change over time. Following game theory terminology, cooperation means enforceable agreements are permitted within coalition C. A human mediator supports the problem solving process of coalition C and he in turn is supported by the GDNSS, MEDIATOR. $\bar{C}$ is the set of all other players not in coalition C who themselves can form one or more coalitions. We note that cooperation is possible only within coalitions so between coalitions -- between C and $\bar{C}$ -- the game is played noncooperatively. Otherwise, if C and $\bar{C}$ cooperate, they can form the grand coalition $C = \eta$.

Using MEDIATOR, the mediator aids coalition C's players in building a public (common) joint (group) problem representation of the negotiation based on the union of individual-player problem representations. The negotiation problem representation--shown by MEDIATOR graphically or as relational data in matrix (spreadsheet) form--involves four spaces and consists of mappings from control (decision) space to goal space to criteria space (and through marginal utility functions) to preference (here utility) space. If goals are not risky, they are used directly as criteria. A problem representation for a group of three players, Table I, is taken from Jacquet-Lagreze and Shakun (1988) and will be used in section 4. The negotiation problem representation also includes a goals/values relation relating goals to values. The various spaces can be redefined while using MEDIATOR. For use of a heuristic goals/values referral process to redefine goal space, see Shakun (1988).

At each stage of the negotiations, the public joint problem representation shows the acknowledged degree of consensus (or conflict) among coalition C's players, i.e., at each stage this joint problem representation may show different individual-player problem representations. The evolution of problem representation can be described as a process of consensus seeking (through sharing of views which constitutes exchange of information) subject to problem adaptation and restructuring within which compromise is possible. At any stage, the mediator can support compromise through use of axiomatic solution concepts and/or concession-making procedures in the MEDIATOR model base. Computer display of the evolving problem representation can be used to support continued consensus seeking. In each space (control, goal, criteria and preference) the negotiation process represents adaptive change, i.e., mappings of group target and feasible sets in seeking a solution--a single point (or set) intersection between them. For further methodological discussion, see Shakun (1988).

In the basic scenario as described above, we think of the mediator as supporting the negotiations and in turn being supported by MEDIATOR, but not himself deciding on them. However, MEDIATOR should also be useful in compulsory arbitration where the mediator decides (chooses) the solution. In some contexts, the mediator can be a group leader, e.g., the president of a company, who finally makes a decision supported by MEDIATOR. In other contexts, MEDIATOR could support the players directly without the use of a human mediator.

1.2 Database-Centered DSS Design Overview

The database-centered approach embeds the decision models and user interfaces of a DSS in a database management environment which provides them with data, stores their execution sequences, and retains their results-- includes not only data management but also model management and multiuser aspects.

In the negotiation support setting discussed here, the database is also used as a communication center among the mediator and the players. Besides providing the initial data underlying the problem to be solved, the data base management system manages the evolving group problem representation. Furthermore, it provides a large number of tools for generating this problem representation and protecting it against unauthorized or erroneous access. The general system architecture is shown in Figure 1 taken from Jarke, Jelassi and Shakun (1987).

FIGURE 1

In Figure 1, each player and the mediator employ a single-user personal DSS which has the traditional three components of model management, data management, and dialog management (Sprague and Carlson, 1982). At present, the single-user DSS for the players makes use of PREFCALC - an interactive program for preference (utility) assessment (Jacquet-Lagreze, 1985; Jacquet-Lagreze and Shakun, 1984). In an enhanced version for the mediator, the marginal utility functions for two or more players can be shown on the same graphical axes to facilitate comparison.

The <u>dialog manager</u> is responsible for effective interaction between the system and its users, namely, each player and the human mediator. It provides menu management, screen composition, and graphics, as well as relational representation facilities (Jarke et. al., 1984).

The model manager consists of executable modules together with modeling language facililties and execution management. In particular, the negotiation modeling in the mediator DSS allows mappings of user changes (or adaptations) in all four spaces (control, goal, criteria and utility).

The data manager accesses and maintains the user's private as well as the jointly acceptable mainframe databases. It contains a standard data base management system (DBMS) with enhanced data dictionary and view management facilities (Jarke et, al., 1984; Jelassi, 1985; Jelassi et. al., 1985). The "data dictionary" stores metadata such as alternative definitions, criteria definitions, function definitions, and units of measure. A "generalized view processor" helps the user define his personal customized view of the underlying database. In particular, alternatives and criterion values can be derived automatically from the stored database records and their attributes.

Each player and the mediator has an individual DSS of this nature. In addition, group decision and negotiation support systems require a communications manager (Figure 1) to integrate the single-user DSS (Bui and Jarke 1984; Bui 1985, 1987).

A conceptual data model for MEDIATOR is shown in Figure 2. Each player and the mediator retains his private databases typically stored on a personal computer. The public shared base data and joint problem representation are stored in a common database located on a mainframe and accessible by all the personal computers. There are also semi-public individual problem representations shared only by particular players and the mediator. The model/method base may contain different tools for each player but they share the PREFCALC method for establishing individual utility preferences on alternatives. Conceptually, this method could be stored in a common model base associated with the common database. From an implementation viewpoint, it is more efficient to have copies on each microcomputer in order to avoid communication delays.

FIGURE 2

After establishing their individual preferences using single-user PREFCALC, players--as they may decide--can transfer their definitions of alternatives and criteria, and their matrix and utility function representations to the common database. Each player occupies a private section of the database which can be only accessed by himself and by the mediator. The mediator will then start the process of integrating these individual problem representations into the group (joint) problem representation.

Once this accomplished, the joint problem representation is stored in the publicly accessible area of the common database. From then on, the "official" negotiation will only work with this joint representation. The players are free to continue using their local representations and other decision support tools for personal deliberations.

Evolution of the group problem representation can lead to

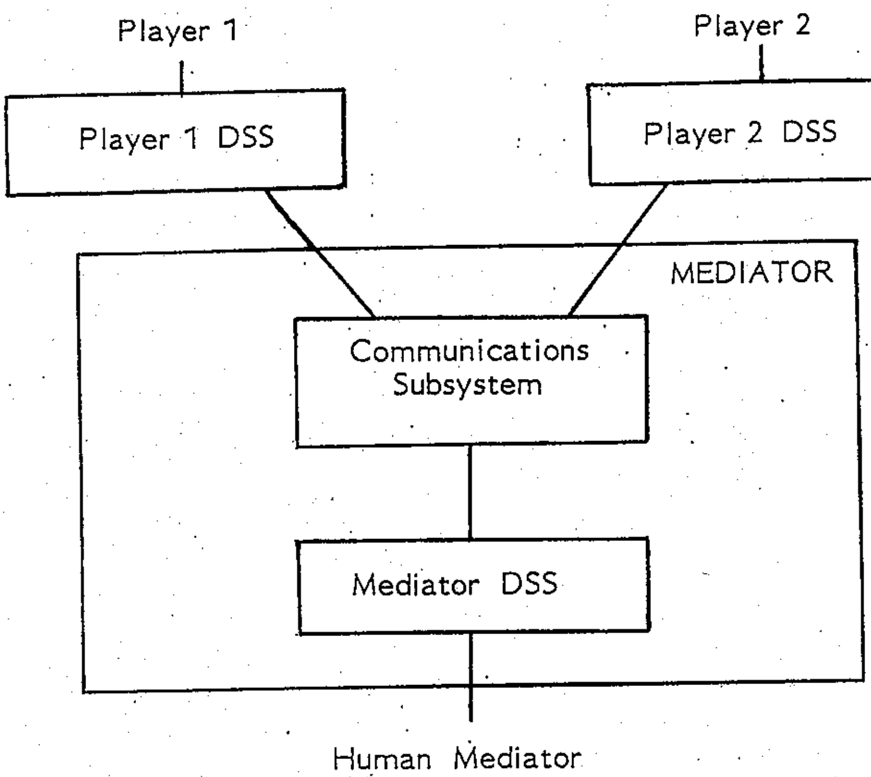

FIGURE 1: General Systems Architecture--Players' and Mediator's DSS

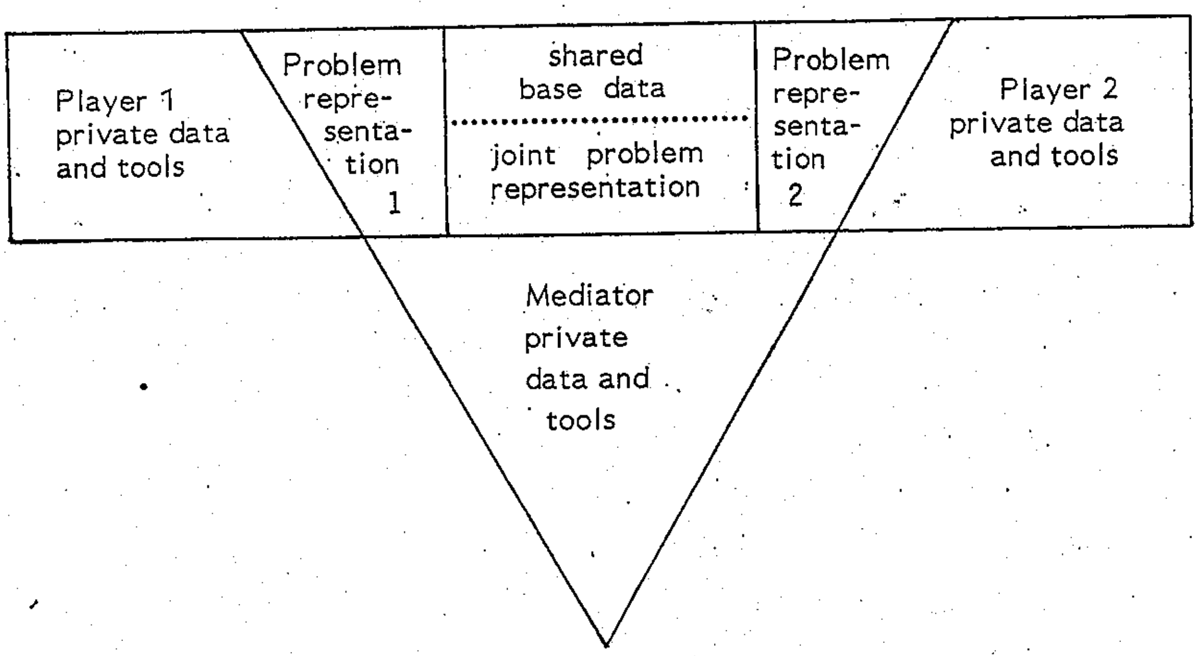

FIGURE 2: Conceptual Data Model for MEDIATOR

restructuring, consensus or compromise on a group decision.

2. COMPROMISE IN GROUP DECISION AND NEGOTIATION

As mentioned in section 1.1 and discussed by Shakun (1988, chapter 9), at any stage the mediator can support compromise through use of axiomatic solution concepts and/or concession-making procedures in the MEDIATOR model base.

The axiomatic approach uses axioms to specify desirable properties that solutions (compromises) should satisfy. For example, the Nash axioms lead to the Nash cooperative solution determined by maximizing the product of the players' utilities measured relative to the conflict payoff. Since players in coalition C can cooperate— enforceable agreements are permitted within coalition C -- the discussion of axiomatic solutions begins naturally with cooperative games -- see Shakun (1988, chapter 9). In fact, the axiomatic approach having been motivated by cooperative games, is often called the cooperative approach. However, if players in coalition C do not cooperate--i.e., play the game noncooperatively--then the axiomatic solution concept which applies is equilibrium and the focus is on players' strategy choices.

A (Nash) equilibrium point is a specified collection of strategies such that every player's strategy is optimal for him given other players use their specified strategies (Nash, 1951; Owen, 1982). Various writers have refined the equilibrium point concept. For example, Selten (1975) restricts solutions to perfect equilibria, i.e., Nash equilibrium strategies which are subgame perfect, i.e., have the property that for every subgame the Nash equilibrium strategy restricted to the subgame constitutes a Nash equilibrium for the subgame. Kohlberg and Mertens (1986) argue for stronger stability properties.

Because the equilibrium concept arises naturally in noncooperative games, the study of strategy choice and equilibirum solutions is called the noncooperative or strategic approach. It is clear, however, that equilibrium is an axiom so that in fact the noncooperative or strategic approach, along with the cooperative approach, falls into the class of axiomatic methods. With these the game is never actually played, only analyzed to find solutions.

We note that at any stage the primary set of equilibrium points available to players—those obtained by independently chosen pure or mixed strategies — can be expanded by them through joint randomization yielding correlated equilibria. The use of a mediator permits the attainment of additional equilibria through restructuring of the game (a) by taking advantage of information coordination afforded by his presence, and (b) by exacting penalties for noncompliance with attractive agreements that would otherwise be unstable. In case (b), Weber (1985) calls the mediator a "regulator". If an intervenor is invited to suggest an agreement, Weber call him an "arbitrator". Weber also defines an "auditor" as an individual (or procedure) through which information held by one player can be made public. Our use of the term "mediator" is intended to subsume all of these functions, i.e., if appropriate, the mediator can support the players in all of these ways.

As Shakun (1988, chapter 9) notes, axiomatic solution concepts may or may not involve interpersonal utility comparisons. Harsanyi (1977) argues that game theory should not use interpersonal comparisons--that solutions should be independent of linear transformations of any player's utility function. However, in the real world, as Harsanyi acknowledges, interpersonal comparisons are made. They are used in such simple social (collective) choice approaches as maximizing the average utility of players, and maximizing the minimum utility of players (maxmin), as well as in more complex ones. Hence Shakun (1988) argues for the availability to players of both types of solution concepts. For a review of social choice theory, see Hwang and Lin (1987).

For games with incomplete information, the main development in game theory has followed the noncooperative or strategic approach. Following Harsanyi (1967-68), the basic idea is to model them as Bayesian games. Here a player puts subjective probabilities on all information unknown to him and he updates these probabilities as additional information arrives. Solutions are (Bayesian) equilibrium points. Selten (1975) argues that solutions be restricted to perfect equilibria, which are conceptually closely related to sequential equilibria (Kreps and Wilson 1982). Harsanyi (1983,1987) and Harsanyi and Selten (1988) deal with the multiplicity problem, i.e., of selecting one specific perfect equilibrium point as the solution to the game. Harsanyi and Selten note that because every cooperative game can be remodeled as a noncooperative game their solution method — involving the tracing procedure— provides a unifying solution approach. Aumann (1987) shows that correlated equilibrium can be viewed as a result of Bayesian rationality.

Myerson (1979, 1986) develops the revelation principal that allows a mediator to express any game with incomplete information as a revelation game in which each player (because of incentive constraints imposed) has incentive -- and it is in equilibrium -- to truthfully reveal his type, private information known to him but not to others. The mediator then seeks incentive-efficient plans, i.e., efficient subject to incentive constraints. He can then choose among the incentive-efficient plans, perhaps invoking some equity criteria. For a generalization of the Nash cooperative solution for games with incomplete information, see Myerson (1984a, 1984b). For practical discussion of some procedures inducing honest revelation, see Raiffa (1982).

Rubenstein (1987) departing from earlier work he cites discusses a two-person sequential bargaining game (in which players make alternating offers) under complete information for which he shows there is a unique perfect equilibrium. He then notes that for a sequential game with risk of breakdown, p, the unique perfect equilibrium (in the limit as p approaches zero) approaches the Nash cooperative solution, thus providing noncooperative (strategic) support for the Nash cooperative (axiomatic) solution. (The generalization of Rubenstein's sequential game to more than two players poses problems, but these disappear in Fershtman's(1987) model involving simultaneous offers in continuous time where he finds a perfect equilibrium for the multiplayer case). Rubenstein then discusses the sequential bargaining game with incomplete information. Here the set of sequential equilibria is very large so there is the problem of selection of one particular equilibruim as the solution. Rubenstein suggests one approach to this.

In contrast to the above axiomatic methods where games are analyzed to find solutions (compromises) but not actually played, concession-making procedures involve actual play of a noncooperative game-- players in fact make a sequence of concessions leading to agreement (a compromise control) or break-off. Shakun (1988, chapter 9) discusses decision support for individual - player concession making. Focusing on goals, concession making in a two- player negotiation is formulated as a problem in stochastic terminal control in which a player specifies and revises subjective probabilities on the concession of the other player in response to his own concession based on past response and new information including evolution of the game. In another approach focusing on controls, a concession making procedure in a multiplayer negotiation involving stagewise expansion of acceptable controls is discussed, as well as its vulnerability to manipulation. Munier and Egea (1988) present a concession-making procedure in which players solve a sequence of interdependent multiobjective programs in seeking a solution.

3. INFORMATION CONTEXT IN GROUP DECISION AND NEGOTIATION

Coalition C's problem solving process involves a within - coalition C game within the game between C and $\bar{C}$. We define a shared information context for group decision and negotiation within coalition C as one where there is full information sharing among coalition C members of all information known or estimated by them. Thus, at any stage of evolution of the public joint (group) problem representation, the public display of such information and the within-coalition C game is complete. Between C and $\bar{C}$, the game in general is one of incomplete information (although it could be complete as a special case) where players in C need to estimate information about $\bar{C}$.

Although approximated in some settings -- see Jarke, Jelassi and Shakun (1987) on group car buying and Jacquet-Lagreze and Shakun (1988) on new product design involving several corporate departments -- in general all information known or estimated by coalition C members is not fully shared among them, i.e., players have some private information. In this case, we define coalition C's group information context as nonshared. Coalition C's public joint problem representation of all information known or estimated by its members is incomplete--may have missing information (not supplied or shared by some of its members) or false information (given falsely by some of its members). Clearly the general case within coalition C is that of the nonshared information context with the shared information context being a special case of it. Examples of nonshared information contexts in group support include labor-management, financial, and international negotiations.

A shared (nonshared) information context -- one with (without) full information sharing--where the within-coalition C game is one of complete (incomplete) information is associated with what has been loosely called a "cooperative" ("noncooperative") context in the GDNSS literature. Negotiation cooperative/noncooperative context is a multidimensional concept. Information sharing is one dimension of negotiation context -- one criterion for distinguishing cooperative from noncooperative contexts. Another criterion is the degree to which a player j's estimates of the preferences of other players are favorably included in player j's preference structure. For example, this can be measured by Shakun's (1976) cooperative behavior coefficient (which measures cooperative behavior at a particular time) and his cooperative solution coefficient (which measures cooperation inherent in a proposed compromise solution). The degree of mutual preference inclusion perceived by players affects restructuring, consensus-seeking and compromise -- a high degree of preference inclusion is associated with a cooperative context. Combining these two criteria (there are others), we would say that high (low) information sharing and mutual (non-mutual) preference inclusion are associated with a cooperative (noncooperative) context. In this paper, we focus on information sharing. We note that Bui, Jarke and Shakun (1987) discuss aspects of noncooperation in GDNSS, especially communications, but do not operationally define criteria for cooperative and noncooperative contexts.

Then, in a shared information context each player in coalition C develops his own individual problem representation (which includes estimated information on chance moves and on the problem representations of players $\bar{C}$ not in coalition C) and sends it to the mediator for inclusion in the public joint problem representation which, in this case, is within-coalition C complete.

If the information context is nonshared, one or more players in coalition C send incomplete individual problem representations for inclusion in the public joint problem representation. Since in this case the latter is necessarily within-coalition C incomplete, each player develops his own private joint problem representation. By this we mean the union of his own individual problem representation and his subjective estimates of the individual problem representations of all other players in coalition C. In the special case of shared information context, all players will have privately the same joint problem representation as the one shown in the public joint problem representation. The latter is within-coaltion C complete although between-coalition (C vs. $\bar{C}$) incomplete if players in C have had to estimate information on $\bar{C}$. In the nonshared information context, at least one player in coalition C will have a private joint problem representation different from the public one.

If privately players do not all have the same group (joint) problem representation (which necessarily means at least one of theirs differs from the official group problem representation), they will be playing a hypergame -- see Fraser and Hipel (1984), Hipel, Dagnino and Fraser (1988) and Wang, Hipel and Fraser (1988) who have developed software for a computerized equilibrium analysis.

4. STRATEGIC MANIPULATION: AN ILLUSTRATIVE EXAMPLE

Consider a corporate group making a new product decision. The group (here coalition $C = \mathcal{N}$, the grand coalition) consists of marketing (player 1), engineering (player 2), and finance (player 3). The product is an ultralight airplane. In Jacquet-Lagreze and Shakun (1988) the case of full information sharing in the group is treated. The public group problem representation (after two evolutions of the problem) is shown in Table I. There are six alternative plane designs, sixteen

Table I: Second Evolved Group Problem Representation

	Controls				Criteria															Utilities		
Plane design	Speed x1	Fuel x2	Price x3	Capacity x4	Sales y11	Sales y12	Sales y13	% errors e11 = e13	Cost y2	Profit y31	Profit y32	Profit y33	Invest y4	% invest return y52	% invest return y53	Speed y6	Fuel y7	Capacity y8	Feasibility y9	u1	u2	u3
A	260	8.6	125	1	100	150	120	8.6	95	3.0	4.5	3.6	19	23.7	18.9	260	8.6	1	1	.02	.43	.29
B	140	14.3	60	1	450	460	450	6.7	50	4.5	4.6	4.5	16	28.8	28.1	140	14.3	1	1	.44	.35	.57
C	120	11.8	50	1	560	560	560	5.9	43	3.9	3.9	3.9	18	21.8	21.8	120	11.8	1	1	.53	.29	.39
D	220	11.5	100	1	230	240	240	4.8	79	4.8	5.0	5.0	17	29.7	29.7	220	11.5	1	1	.47	.42	.71
E	160	12.4	80	2	470	400	440	9.0	65	7.0	6.0	6.6	21	28.6	31.4	160	12.4	2	.95	.77	.58	.57
F	210	9.9	120	2	250	290	270	9.0	95	6.2	7.2	6.7	22	33	30.7	210	9.9	2	.95	.69	.67	.55
Ideal					560	560	—	4.8	—	7.0	7.2	6.7	22	33	31.4	260	14.3	2	1	1	1	1
Anti-ideal					100	150	—	9.0	—	3.0	3.9	3.6	16	21.8	21.8	120	8.6	1	.95	0	0	0

criteria and three utilities, u1, u2, and u3 for the three players. Under full information sharing, the private group problem representations of the three players are the same as the public one. After 0-1 normalization, the utilities are given in Table II. If the maxmin compromise solution for the group is used, the decision is plane E.

Next consider a case of nonsharing on the part of engineering who tries to manipulate the solution by giving false utility information. Engineering, of course, knows his own true utilities u2. He estimates that marketing's (player 1) first choice is E, then F giving a normalized utility u1=1 for E and estimating u1=.8 for F. He estimates normalized utilities for B, C and D at about u1=.5 each and for A at u1=0. For finance, engineering estimates u3=1 for plane D (engineering estimates plane D is finance's first choice), u3=.8 for B, u3=.7 for E, .5 for F, .3 for C, and 0 for A. Using his own true normalized utilities gives engineering Table III with plane E--engineering's second choice (he prefers F)--as the maxmin solution decision.

Engineering feels the other players will fully share information and will report their true utilities to the mediator. He is tempted to manipulate the solution by reporting false utilities u2. In Table IV he determines the effect of his switching his utility values u2 for planes A and E is to change the maxmin solution to plane F, his first choice.

He decides to do this. With marketing and finance reporting their true utilities, Table V shows the actual effect of engineering's manipulation is to change the maxmin solution to plane F, as he had calculated in Table IV.

TABLE II
SECOND EVOLVED NORMALIZED UTILITIES

Plane	Marketing u1	Engineering u2	Finance u3	Minimum Utility
A	0	.37	0	0
B	.56	.16	.67	.16
C	.68	0	.24	0
D	.60	.34	1	.34
E	1	.76	.67	.67
F	.89	1	.62	.62

Maxmin Utility = .67
Maxmin Compromise Solution is Plane E

TABLE III

Second Evolved Normalized Utilities Estimated by Engineering for Marketing and Finance with Engineering's True Utilities

Plane	Marketing u1	Engineering u2	Finance u3	Minimum Utility
A	0	.37	0	0
B	.5	.16	.8	.16
C	.5	0	.3	0
D	.5	.34	1	.34
E	1	.76	.7	.7
F	.8	1	.5	.5

Maxmin Utility = .7
Maxmin Compromise Solution is Plane E

TABLE IV

Engineering's Calculated Effect on Solution of Manipulation--Reporting False Utilities u2

Plane	Marketing u1	Engineering u2	Finance u3	Minimum Utility
A	0	.76	0	0
B	.5	.16	.8	.16
C	.5	0	.3	0
D	.5	.34	1	.34
E	1	.37	.7	.37
F	.8	1	.5	.5

Maxmin Utility = .5
Maxmin Compromise Solution is Plane F

TABLE V

Actual Effect on Maxmin Solution of Manipulation by Engineering of his Utilities u2

Plane	Marketing u1	Engineering u2	Finance u3	Minimum Utility
A	0	.76	0	0
B	.56	.16	.67	.16
C	.68	0	.24	0
D	.60	.34	1	.34
E	1	.37	.67	.37
F	.89	1	.62	.62

Maxmin Utility = .62
Maxmin Compromise Solution is Plane F

However, it is not clear that in real life engineering would engage or succeed in this manipulation. Since a corporate group making a new product decision involves, in principle, a shared information context, one of the group members might suggest that players exchange information on their marginal utility functions obtained here as graphical output from PREFCALC. If engineering refuses or cannot produce underlying marginal utility curves consistent with his false utilities, he will be suspected of giving false information. Further, engineering's utility manipulation could work against him if other solution concepts besides maxmin are invoked by players. This could act as a deterrent to manipulation. In addition, a player may be nonmanipulative in principle especially if he thinks other players are also nonmanipulative. Lewicki (1983) develops a behavioral model of lying and deception that may have potential use in group decision and negotiation support. Also behaviorally, players would tend to refrain from manipulation where this would require complex analysis and collusion with others.

Still, the example illustrates the possible of successful stratgic manipulation when the victimized players assume a shared information context, i.e., assume the game has complete information when in fact it is incomplete due to false information. The sensitivity of various social choice procedures to strategic manipulation has been studied-- see Nurmi (1984, 1986) and Riker (1986) -- and the findings, while still limited, can be used by MEDIATOR.

5. MEDIATOR IN EVOLVING, NONSHARED INFORMATION CONTEXTS

We discuss the case of evolving, nonshared information contexts where the mediator using MEDIATOR is supporting coalition C which may change over time. In general, the within-coalition C and C vs. $\bar{C}$ games are games with incomplete information that are evolving. At any stage a player in coalition C can have private information known to him but unknown to at least one other player in that coalition. Information unknown to a player j ($j \in C$) remains unknown to him if some other player who knows it has not sent it to the mediator for sharing with player j (i.e., missing information) or has sent false information. In either case information is within-coalition C incomplete for player j so he develops his own private joint problem representation using information he knows (e.g., information about himself) and making subjective probability estimates for all other incomplete information regarding other players in C as well as $\bar{C}$. (A simplification--sometimes justifyable under cognitive or computational overload--would be to use point estimates). He updates these probabilities as additional information comes to him. The judgment as to whether information supplied by some other player in C or $\bar{C}$ is false is left to player j. If he deems it false, he places a probability of zero on it and subjectivly makes his own estimate of the information.

For a noncooperative game (section 2), since the purpose of player j's developing a subjective estimate of the individual problem representations of other players would be to estimate what controls they will exercise, the alternate approach is for player j to specify directly subjective probabilities on these controls. For the C vs. $\overline{C}$ noncooperative game, based on these probabilities on $\overline{C}$, player j who is a member of coaltion C will recommend that coaltion C choose a control which gives an output (goal) probability distribution preferred (optimal) for him. Other players in C will want coalition C to choose other controls preferred by them. This within- coaltion C conflict (game) can be played either cooperatively or noncooperatively, and solved by axiomatic methods or, for the noncooperative case, by concession making (actual play) within coaltion C to arrive at a compromise control for coalition C to play against $\overline{C}$. This approach follows the general ESD mathematical formulation for the C vs. $\overline{C}$ game (Shakun 1988, chapter 1). Playing against a set of controls available to $\overline{C}$ (or subjective probabilities on this set), coalition C controls to a preferred output (goal) set (or probabilities on the set). Of course, if different players within coalition C have different subjective probabilities on $\overline{C}$'s set of controls, then coalition C will control to a preferred set of output probabilities associated with the compromise control chosen by it. In other words, coalition C's chosen compromise control (strategy) is optimal (preferred) against its specification of $\overline{C}$'s controls. If actual play of the C vs. $\overline{C}$ game occurs, the procedure provides C with its present control, i.e., the control to be actually implemented in the present time period.

As discussed in section 1.1 and in more detail by Shakun (1988), the mediator using MEDIATOR based on ESD supports the evolution of the group (coalition C) problem representation, i.e., the problem is ill-structured and evolves. This evolution can be described as a process within coalition C of consensus seeking (though sharing of views, which constitutes exchange of information) subject to problem adaptation and restructuring within which compromise is possible. In a nonshared information context, at any stage the within-coalition C and C vs. $\bar{C}$ games are games of incomplete information, but also these games evolve over time. Thus, at any stage MEDIATOR can use game theory and related approaches (section 2) for restructuring and finding compromises. However support over time by MEDIATOR under ESD goes beyond this to support evolution (change) of the group problem representation through cybernetics/self-organization: (a) problem adaptation through learning associated with negative feedback/feedforward and (b) problem restructuring (reframing) associated with positive feedback/feedforward--e.g., the heuristic controls/goals/values referral process (see Shakun 1988). To illustrate, goal space can be redefined. Preferences can be reconstructed on the same or redefined criteria space. Computer display of the coalition C evolving problem representation can be used to suggest continued consensus seeking--information exchange (here partial), problem adaptation and restructuring, seeking to move to the same preferred solution for all players in coalition C. Other artificial intelligence techniques -- use of knowledge bases, case-based reasoning (Sycara, 1988), etc., can be used for problem evolution and compromise.

The process of building a public joint (group) problem representation stimulates information sharing. Supported by MEDIATOR, the mediator can encourage movement towards information sharing as much as possible. Using the communication subsystem, the mediator can focus on socio-emotional aspects of negotiations (as well as task) attempting to build interpersonal relationships and an increased atmosphere of trust and sharing. This can lead to increased information sharing and favorable consideration of others' preferences. Faure, Le Dong and Shakun (1988) include socio-emotional aspects as well as task in the problem representation.

Even if players do not share much information directly with each other, the mediator can encourage coalition C players to share information confidentially with him. Then the mediator's own private joint problem representation can be considerably more complete then those of the players or the public representation. As a result he may be able to help negotiations evolve, or later suggest a post-settlement settlement (Raiffa 1985), an improved alternative settlement to the one players have settled on that all coalition C players may prefer.

Especially in complex negotiations and where players are reluctant to share information, the mediator can use a single-negotiating-text procedure. Here the mediator prepares a single negotiating text, the players react to it, and then he successively modifies it--see Raiffa (1982).

Restructuring can be a powerful method in nonshared information contexts. In negotiations to free hostages (Faure and Shakun, 1988) where players are very hostile towards working together and sharing information, the mediator using MEDIATOR builds his own private joint problem representation. Although outwardly it appears that players do not have common values -- making agreement on operational goals much more difficult -- the mediator, supported by a heuristic goals/values search process, finds common values and a new operational goal dimension to restructure the negotiation. Such restructuring by the mediator can be an integral part of a single-regotiating-text procedure.

Use of the goals/values referral process for restructuring negotiations by cybernetics/self-organization (Shakun 1988) can in the process sometimes shift the context to more information sharing than before. Otherwise put, blocked negotiations and blocked or restricted information sharing often go hand-in-hand. The process of restructuring can often unblock negotiations and stimulate information sharing.

Frequently players in a group decision and negotiation problem come from different cultures, e.g., different national cultures (American, Japanese, French, etc.) or professional cultures (marketing, engineering, finance, etc. in a company). In general, different cultures can exist among different organizations (players). A problem representation may be viewed as a culture. When such players build an evolving public joint (group) problem representation showing evolving similarities and differences, they are generating an evolving common joint (group) culture with regard to the problem at hand. This culture includes the decision support technology used. By aiding the players to build an evolving common culture--expressed through the evolving public group problem representation--the mediator and MEDIATOR can help players overcome cultural barriers (i.e., conflict rooted in cultural differences), thus supporting arrival at a group solution. The process can result in evolutionary change in relation among the players. For building a common culture in negotiations involving different professional cultures--marketing, engineering, finance-- see Jacquet-

Lagreze and Shakun (1988) and David (1987). Shakun (1988, chapter 3) provides an initial public group problem representation-- a controls/goals/values relation-- as a point of departure for players in the Arab-Israeli conflict to try to build a common culture with regard to the problem. In negotiations to free hostages (Faure and Shakun, 1988), the search by the mediator for shared values and goals is at the heart of the suggested negotiation support.

These are ways in which mediator/MEDIATOR can support group decision and negotiation in evolving, nonshared information contexts. The better we understand the mediation process, the better MEDIATOR can support the mediator in his work. As discussed by Faure (1987), the mediator himself is a player with his own set of goals who need not be impartial and neutral and whose own stategies (controls) are limited by accepted mediation norms. Thus, the mediator himself can be included as a player in the group problem representation.

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