Perspectives on Representation and Analysis of Negotiation: Towards Cognitive Support Systems *

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Abstract. The rapid expansion of Decision and Negotiation Support Systems has been built mainly on decision theoretic approaches. This has resulted in the decision maker being viewed through the lens of the problem. In this paper the focus is on the decision maker's view of the problem. Three levels of problem articulation are described. Special emphasis is placed on the needs level and the implications it carries for the cognitive and instrumental levels. The three levels of articulation, the organizational model of making decision in social settings and the three basic approaches to decision making form the basis for computer support focused on understanding and change rather than preferences and outcomes. We argue that in the dynamic, interactive context characteristic of negotiations, a cognitive support system based on restructurable modelling provides a richer basis for support.

Keywords: Decision making, Negotiations, Rationality, Conflict resolution, Restructurable modelling, Decision support, Negotiation support, Cognitive support

1. Introduction

Investigations into the practice of supporting group decisions and negotiation have grown and matured remarkably in the past decade. Software has developed from a few limited algorithms to a range of commercially available packages (Bui, 1994; Fang, Hipel and Kilgour, 1993; Friend, 1989; Vogel, 1994; Lewis and Shakun, 1994; Thiessen and Loucks, 1994). Conclusions concerning the effects of support utilization have evolved from primitive single-case studies to sophisticated experiments and numerous field observations (Eliasberg et al., 1992; Connolly et

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al., 1990; Teich et al., 1994; Weisband, 1992). Permanent facilities have been built which can support both experimental programs and utilization by managers confronting real issues (DeSanctis et al., 1991; Nunamaker et al., 1991). The emphasis in the field has shifted from basic conceptualization and development to refinement and evaluation.

While the provision of support systems has expanded, in many cases the theoretical justification for their structure and operation (and associated research designs) have not kept pace. There is little direct linkage between the behavioral theories of decision making and the design and operation of group decision (GDSS) and negotiation support systems (NSS). For the most part the problem has not been one of a lack of theories but of the number of theories that impinge on the field, their diverse origins and the varying conceptualizations of the decision making process that they assume.

In this paper we examine the decision making process in light of behavioral and cognitive approaches, to provide a consistent description on which support processes can be based. Behavioral research provides a social context and alternative explanations for a decision maker's cognitive activities, including her capacities for problem perception, problem solving, choice, evaluation and learning (Heylighen, 1992; Newell, 1990).

From the behavioral point of view it is clear that the decison maker's needs and cognitive facility define her ability to utilize various forms of support. While this point of view has been acknowledged, it has, until recently, rarely affected the development of DSS (including GDSS and NSS). What is more important for this paper is that needs and cognitive abilities also have important implications for the the interaction of user and support system; depending on the nature of the system it may enhance the user's abilities to a greater or lesser degree or perhaps even degrade them. With the exception of some work from the European Schools (e.g. Angehrn, 1993; Eden, 1992; Roy, 1990) this implication has been almost completely ignored.

In the cognitive approach, the decision maker defines the decision context through her perceptions (Weick, 1979). Three approaches to understanding decision making, intuition, analogy and generalization, are considered in terms of this analysis. After examining general approaches to decision support, the specific problems associated with supporting negotiations are considered and a comprehensive view of the nature of decision and negotiation support is given.

One theoretical approach, historically the most important, stems from the evolution of GDSS and NSS from DSS and decision analytic approaches. Decision analysis is mainly concerned with the representation and solution of those specific aspects of problems for which some decision quality measure can be determined under the assumptions of axiomatic rationality. The explicit or implicit existence of such a measure, coupled with the decision maker's ability to employ it, is the cornerstone of many formal methods.

Within decision analytic approaches support tools are often used in an instrumental and inflexible manner (Angehrn, 1993). The relationship between the user and the tool is fixed by the assumptions of an underlying method and, often, by its specific implementation. There is little empirical work on possible interactions between tools and decision context. To what extent are the uses and outcomes of a particular approach altered by interaction with the situation in which the choice is made? This is a two level problem. The tool must support the particular decision but a decision must also be made concerning which tool to use. For decisions which may require rapid and continuous redefinition of the problem, such as strategic decisions and negotiations, a single method or tool may not suffice.

In our attempts to design support for decision makers in different settings (e.g., union-management negotiations, strategic foreign investment, supplier-manufacturer agreements, medical case management, reforestation) the limitations of tools based on decision theoretic methods have become clear. First, these tools do not support a significant portion of problem solving efforts, including formulation and reformulation of the decision problem. Second, they assume congruence between the formulae derived from axioms and the decision maker's representations that is seldom warranted. Third, they do not integrate other types of theories with decision theory. Fourth, they require the simultaneous consideration of all decision alternatives, preferences and outcomes, excluding the possibility of evolving perspectives. Fifth, they ignore, in most cases, the concepts of time, process, fairness and flexibility and the ability to make future decisions.

There are numerous applications of game and decision theoretic models to explain and support negotiation. The game theoretic assumptions of perfect rationality and perfect or near perfect knowledge of all parties (Harsanyi and Selten, 1988) led to the prescriptive/prescriptive approach (dictating what all the parties should do to achieve a stable compromise). These assumptions were weakened with Raiffa's (1982) prescriptive/descriptive approach in which prescriptions are developed for one side that "...assume *intelligent, goal-seeking action* by the other parties, but not full game-theoretic (interactive) rationality" [emphasis in the original] (Sebenius, 1992). This approach, while very fruitful and significantly expanding the analysis of negotiation and parties' behaviour (e.g., Bazerman and Neale, 1991; Lax and Sebenius; 1986), does not provide an adequate basis for support. The explanatory power of the prescriptive/descriptive approach resides in the enriched analysis of opponents that it provides at the cost of maintaining a rigid and mechanistic perspective of the supported party. This led NSS developers to use their systems successfully in teaching and training enviornments rather than in supporting real-life negotiations (e.g., Rangaswamy and Shell, 1994; Teich et al., 1994; Tung, 1994).

Methods that address these difficulties are based on a theory of personal constructs (Bonham, 1993; Eden et al., 1979; 1983), soft systems methodology (Checkland, 1989), or the strategic

choice approach (Friend, 1989). Our method, called restructurable modelling, is based on AI principles and the cognitive insights on which they are built (Kersten and Szpakowicz, 1994a; Kersten and Szpakowicz, 1994b). This allows us to use inference mechanisms to formulate and reformulate representations and to reason about the implications of decision problem.

Restructurable modelling is a framework that allows the decision maker to generate stories describing sequences of situations. Development of a description of any particular situation may be based only on qualitative structures; it then takes a form of a text. The description may also involve quantitative representations, derived, for example, from decision theory. A sequence may reflect the interactions between the decision maker and other agents, evolution of her perceptions or alternations in problem specification. This focus on cognitive efforts led us to suggest that computer-based support systems based on restructurable modelling are *cognitive support systems*.

To understand the implications of an approach based on restructurable modelling one must first consider the nature of decision making, focusing on the levels at which decision makers encounter the decision process. Initially three levels, needs, cognition and support, are examined in light of three perspectives on decision making, intuition, analogy and generalization. In most current formulations decision support emphasizes the support level while taking little notice of the needs of the user or her cognitive abilities. Our purpose is not to propose a detailed theory of computer-based support, but to discuss the basic issues that such a theory must confront. (The reader may find it useful to refer to Fig. 3 which provides a summary of these issues.) The discussion is framed in terms of an AI based, cognitively informed approach to supporting group decisions and negotiation.

2. Reasoning about decisions

2.1. Levels of articulation

Decision theory provides decision makers with a wide range of instruments which can be applied to different situations to uncover existing relationships and to help represent, analyze, solve and evaluate the decision problem. The selection and use of a specific method is, however, inherently subjective and guided by the agent’s preferences expressed in her current understanding of the situation. Typically, it is assumed that preferences remain stable, at least for the duration of the choice process, and the selection of a support tool is compatible with these preferences

This outlook essentially places choice and reasoning about choice at one level. However, the framing of choice and its impact can be articulated by the decision maker or analyst at three distinct levels:

- the level of needs and values,
- the cognitive (intellectual faculties) level, and
- the instrumental level.

The *needs level* draws from Maslow's work (1954) in which he proposed a hierarchy of human needs. In his view the activation of a need provides the rationale for specific actions the agent undertakes to solve problems and make decisions. Decision making is seen as a purposeful process which orients action to addressing an unfilled need or to attaining a higher degree of need fulfillment (see laso, Vroom, 1964). While the need level introduces the normative aspect to the decision process, the norms are anchored in the agent and the history of the agent's actions and interactions. The activation of a need does not necessarily lead to a specific means for meeting that need nor to a particular way of determining action.

At the level of needs articulation the normative perspective is invoked. It is, however, a departure from the normative decision-theoretic viewpoint (Bell, Raiffa and Tversky, 1988) in that such a normative conception of choice does not necessarily posit the five axioms of decision theory (Savage, 1954). Experimental work (e.g. McNeil, Pauker and Tversky, 1988) indicates that consideration of different aspects of a problem, even a change in its presentation, often invokes different reactions. These reactions may be caused by a change in needs hierarchy or activation of new associations. A theory of decision support should assess and accommodate such shifts in the relation of the decision process to the underlying need.

The *cognitive level* links a decision opportunity to the ability to realize certain needs (Heylinghen, 1992). This involves the recognition of the type of problem, whether it is novel or routine, the definition and interplay of its components and its relation to earlier experience. While Maslow (op. cit.) argues that individuals respond to a given level of needs only after lower levels are satisfied, specific needs within that level can be fulfilled in a variety of ways. Thus, decision making articulated at the cognitive level includes connecting opportunities to satisfy needs with aspects of the problem. This may involve specification or transformation of needs so that they correspond to the potential decision outcomes. The significant aspects and relationships of the problem are considered, major difficulties or obstacles in determining a solution are specified, and the relationships between possible decision outcomes and needs determined. Decisions concerning problem solving strategies and methods that can support problem solving are also made at the cognitive level.

The cognitive level corresponds to the intelligence phase in Simon's (1960) model of problem solving in that it involves recognizing other efforts to represent the problem and determining their relevance to the agent. It also partakes of Mintzberg, et al's (1976) problem definition stage since it requires the agent to abstract from a situation (which may be highly complex and ambiguous) a decision problem which is coherent enough to be addressed. Problem definition

may include choosing among alternative means of satisfying needs and will almost inevitably involve implicit choices about levels of need fulfillment including the satisfaction of needs through the decision process as well as through its outcome.

While it is hard to conceive of a considered decision that could be made without being articulated at needs and cognitive levels, many routine and simple decisions are made without the use of the third, *instrumental level*. At this level instruments (tools, methods and mechanisms) are used to reduce the mass of information or the complexity of the problem. This may occur because the agent is not able to deal with the problem requirements, because the agent chooses to simplify the problem or simply because the tool is at hand.

Novel and complex decisions that require processing of a significant amount of information generally need some form of support. This support may come from other agents acting as advisors or the decision maker may use methods to represent, analyze and solve certain parts of the problem. It has been recognized that external support cannot replace the decision maker, but can only provide help in the recognition and better understanding of her own needs, abilities and relationships between needs and cognitive representations. Support can also help to specify difficult elements of the problem. These specifications are *complementary representations* that are used to define decision alternatives, make choices and perform evaluations.

The activities at the instrumental level involve the use of complementary methods and procedures to determine the set of feasible alternatives, determine preference structure and measures of alternative quality, and to conduct sensitivity analysis. Each of these activities involves individual decisions, for example, about the scope of simplification and relevance, the selection of alternative methods and their application, and the adjustment of selected alternatives due to simplifications and assumptions made for the purpose of applying a particular set of instruments.

As indicated in Fig. 1 all three levels of problem articulation may be present in each phase of Simon's model. The importance and scope of each level of articulation, although not indicated in Fig. 1, are likely to vary considerably through the phases. For example, needs would normally be much more prominent in the intelligence and choice phases than the implementation phase. The importance and scope will depend on a number of factors, including the decision topic, its complexity and its familiarity to the decision maker. At the instrumental level different tools may be appropriate for different phases. The implication of this for a theory of decision support is that both the level at which the need for support is generated and the type of support required (and available) is likely to shift from phase to phase of the decision process.

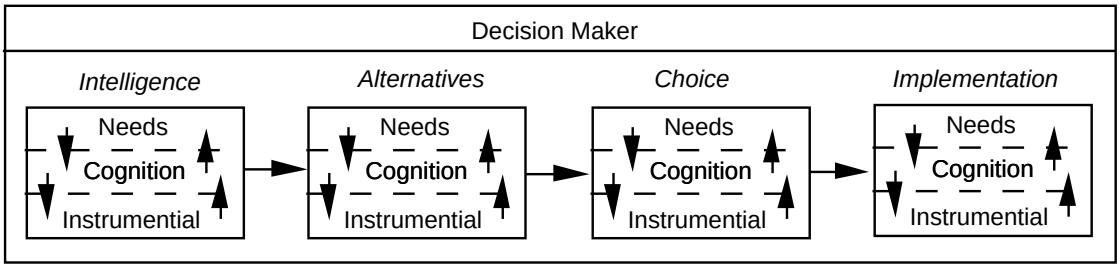

Figure 1. Simon's phase model and levels of articulation

A more general theoretical approach to decision support requires that the needs of the decision maker be incorporated into the model of decision making. This implies that the articulation of needs may change over the course of a complex decision and that increased complexity will increase the likelihood of change. The cognitive predilections of the agent acting as the link between needs and context provide both a template for support and a limitation on its utilization. A decision maker is unlikely to use a decision support system that is incompatible with her enacted environment either in terms of the decision elements or the decision process. This does not imply that support tools must be molded to the requirements of a specific decision maker but that they need to be flexible and able to match her cognitive abilities.

2.2. Organizational model

Decisions are made in a given setting or *situation* perceived by the agent. The "agent's world divides up into a collection, or succession, of situations: situations encountered, situations referred to, situations about which information is retrieved, and so on" (Devlin, 1991, p. 30). A situation contains explicit representations of entities at a given time. Levin (1935) argued that an agent's behaviour is the function of an interaction of two entities: the agent and the environment in which the agent operates. The agent has needs and values that are carried from situation to situation and encounters problems that are solved within a given state (situation) of the environment.

The distinction between the agent and the environment has been accepted in many methods devised for individual decisions. From the assessment or analysis of the states of the environment, constraints and bounds that restrict the feasible alternatives are formed. There is a large class of decisions, however, that requires further specification of the environment as the decision unfolds. These are sequential decisions which require the agent to individuate some entities from the environment. The agent must take into account the needs and actions of the entities as well as their reactions to her own decisions. Cooperation and negotiation are examples of such decisions where other *participants* are closely involved in the process, can be clearly identified and individually represented.

In addition to the restrictions flowing from the participants' involvement, their needs and

values are also considered. The agent and the participants (opponents in negotiations) are interdependent and both actively participate in the process. Therefore, we distinguish three classes of distinct entities:

- the agent who makes decisions,
- the other participants in the decision process, and
- the environment in which the agent and the participants work.

The environment consists of those entities which are not individually identified. The environment is often unstable; it may change either spontaneously or because of the agent's decisions. The environment provides the broader context in which the agent makes decisions. It is characterized by information about its past, present and possible future states but not about its inner structure.

The agent, the participants and the environment constitute the *world*. The world consists of entities and relationships among them. Relationships express the roles and places that entities have in the world. The structure of the world and the relevant relationships are subjectively determined by the agent in that she distinguishes between the participants and the environment.

The world is constructed by the agent and it includes representations of the problem, interpretations of the behaviour of the participants and the environment, and the specific relationships between all entities. In Weick's (1979) phrase this is the "enacted environment". The agent cannot operate directly in a world which she does not construct. The decision has to be understood in terms of the needs of the decision maker and their relationship to the enacted environment. Interpretation and analysis are done on the agent's representation of the world. Mechanisms that act on the representation reflect the agent's needs and cognitive abilities.

2.3. Approaches to decision making

Decision making is a generic process which occurs at the individual, group, organizational and meta-organizational levels. At all levels decisions are motivated by the needs of the participants. In decision support one is normally concerned with decisions made to fulfill higher level needs, that is, norms and values (Keeney, 1992) involving justification and rationality.

While there are identifiable differences in decision making skills and styles, the conviction that there are also common characteristics of decision makers has led to a large volume of studies in philosophy, psychology, sociology and political science. This research aims at analyzing human decisions through representing real processes in terms of manageable and interrelated concepts. It provides a basis for the enrichment of human approaches to decision making through the generalization, formalization and integration of a wide variety of concepts.

Decision makers are seen as using three basic approaches to decision making:

- intuition
- analogy, and
- generalization.

People make decisions intuitively, based on common sense and knowledge acquired through experience. This approach may be used when information is scarce or time does not allow data collection or analysis. It is increasingly difficult and ineffective to employ intuitive decision making approaches in novel, information-rich and complex situations (Simon, 1982). An inability to explain the process leading to a choice and discontinuity in reasoning are characteristic of the intuitive approach. This makes it extremely difficult to support intuitive decision making (although attempts have been made to train individuals to utilize intuition). For this reason we will not be concerned with intuitive approaches in this discussion. However, an important requirement for support is to discover possible discontinuities and inconsistencies resulting from intuition and unstated assumptions.

A second approach is based on the concept of analogy. The problem at hand is compared with problems previously solved (by the decision maker or by others). If similar problems were solved in the past then their solutions are adapted to the current problem. Alternatively, elements of past problems and their solutions are used to construct a parallel abstract problem and its solution. This solution is then translated to the new situation. This implies a specific cognitive approach by the decision maker focusing on recognition of pieces of a problem-solution conjunction rather than more abstract patterns of decision elements.

Reasoning by analogy or case-based reasoning has recently attracted more attention from cognitive scientists and researchers in artificial intelligence (Kolodner, 1993; Schank, 1982). Formal methods for case representation, retrieval, adaptation and evaluation have been developed and implemented.

Holtzman (1989, p.12) says that generalization consists of the representation of the decision problem in terms of a formal decision method and the associated algorithmic techniques. This definition is both too narrow and too broad. It is too narrow, if formal decision methods are only those developed within decision theory. It is too broad if it includes any formal method used in decision making; it would then include case-based reasoning.

Bartlett (1932), Brewer and Nakamura (1984) and other psychologists argue that the third approach to decision making is based on the use of generalizations, composite cases or schemata. Schemata involve the representation of similar cases describing frequently occurring experiences that are merged together and from which minor differences are removed. Scripts, introduced by Schank and Abelson (1977), are a particular version of schemata proposed as a method for knowledge representation and the solution of recurring problems.

In attempting to construct a general approach to decision support, we are especially interested in novel and difficult decision problems since they often highlight factors which are obscured in more routine decision settings. It is often difficult to apply internal schemata in these cases because the decision maker has no experience in solving similar problems. However, others may have solved such problems in the past and their generalized experience may be accessible as an opinion, belief or principle. Behavioural theories are another form of generalization that can be used for decision making.

Formal methods and algorithms are useful means for representing behavioural theories to enable their access, verification, comparison and use for support. Methods such as different types of logic, influence diagrams, decision trees and belief networks can be used to structure behavioural theories and composite cases and represent them in a form that can be manipulated by a support system. Other methods can be used to represent and solve a specific part of the decision problem. The solution may then be analyzed in light of one or more behavioural theories and this analysis, in turn, may result in modifications of the problem representation and the decision maker's needs, preferences, assumptions, etc.

The use of behavioural theories, composite cases and other generalizations requires reasoning on the representations of the decision maker and her problem so that their features and aspects that can be compared with the available generalizations. We view the ability of a support system to provide such reasoning and interpretations of the overall situation based on the generalizations as primary. Typically, there is a need for numerical representations of some parts, their measurement and thus appropriate methods are required. These methods, however, are secondary in that they are used to allow or facilitate interpretation and understanding. In other words, we view the information processing effort associated with the use of generalizations (and also analogies) to be at the cognitive level while the effort involved with the representation and solution of certain parts of the problem are at the instrumental level.

The relationship between the two models of and the three approaches to decision making are depicted in Fig. 2.

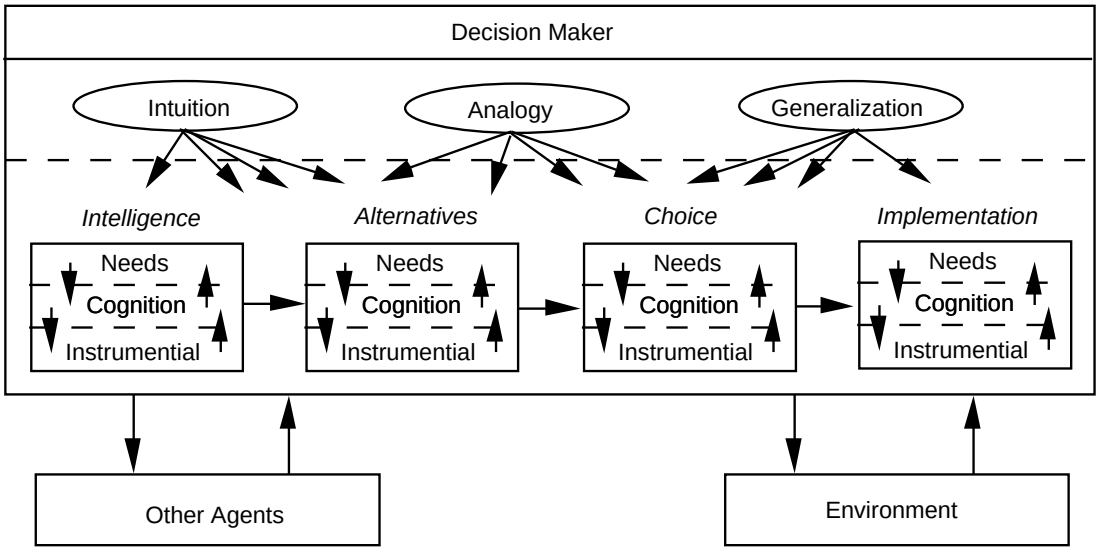

Figure 2. An integrated perspective on decision making

2.4. Decision making and negotiation

Bell, Raiffa and Tversky (1988) differentiate between descriptive, normative and prescriptive decision methods. Raiffa (1982) extends this classification to negotiation and suggests that a system should provide prescriptive representation of the negotiator and her problem and descriptive representation of the opponents. We further consider this distinction in Section 5 in terms of the requirements for negotiation support.

The primary benefit of prescriptive methods is that they may help to uncover or avoid human bias and cognitive illusions. By using decision theoretical methods individuals or groups may realize inconsistencies, uncover their unstated assumptions, clarify the distinctions between constraints and objectives, and determine the relationships between their stated preferences, decision alternatives and outcomes. These methods focus on elicitation of information and its consistent processing to determine and order decision alternatives. They are not grounded in the decision context, the particular psychological and social situation of the decision maker, or her needs and abilities. Thus, these methods have limited capacity for helping decision makers to avoid their cognitive biases, to overcome their tendency to oversimplify, overestimate, underestimate or focus on irrelevant aspects of the decision problem (discussed, for example, by Ungson and Braunstein, 1982; Tversky, 1972; Tversky and Kahneman, 1981).

The point is that decision theory provides one with a generic perspective. It does not take into account past histories and cases, psychological attitudes, small group dynamics or leadership, for which behavioural methods have been developed and successfully applied. Research in psychology, sociology, linguistics and philosophy provide explanations for human behaviour, different forms of rationality, and change in perspectives. In addition to decision theory and game theory, negotiations are analyzed from the point of view of organization theory, small

group theory, coalition theory, and leadership theory, to name a few. Within these theories models and methods have been developed that have significant explanatory powers and which should be used in negotiation analysis and support (Kremenyuk, 1993; Zartman, 1994). To obtain this goal methods for representation of and reasoning about particular decision problems and relevant theoretical models are needed.

Cognitive science and artificial intelligence provide formal methods for the representation of knowledge and reasoning which can be used in both analogical and generalized approaches to decision making. This has been recognized in recent research on DSS which attempts to integrate AI and decision theoretic methods in order to expand the areas of support from problem solving to problem representation and symbolic reasoning about problems (Holtzman, 1987; Klein, 1994). We suggest that these methods should be used to integrate different approaches to representing and solving decision problems, including negotiation problems.

3. Decision Support

3.1. Difficulties in DSS use

The three general perspectives on decision making outlined above are relevant not just to individual decision makers but also to negotiations and other forms of decisions involving multiple agents. The next step is to consider the implications of this discussion for the support of group decisions and negotiations. Before turning to that discussion some general characteristics of decision support must be examined since negotiation support draws extensively from the support for individual decisions.

Many users of DSS have experienced difficulty in learning how to use a system properly and effectively. These problems stem from an incomplete understanding of the methods and procedures used, the complexity of the relationships embedded in the system's functions, seemingly incompatible requirements of different methods, unexplained processing, system requirements that have little meaning to the user or are difficult to satisfy, and difficulty in tracking the consequences of changes in input for output (Beulens and Van Nunen, 1988; Gottinger and Weimann, 1992; Turban and Watkins, 1986). These difficulties have led to the use of human intermediaries or facilitators, for example, decision analysts. This, however, defeats the very purpose of the system which then does not directly participate in the decision process.

A further difficulty in the utilization of many DDS is their inflexibility. Increasing information overload, the complexity of decision-making processes and changes in the decision environment make the use of intuition and unaided expertise inadequate. On the other hand, the formal structures provided by DSS are often difficult to adapt to new situations and may

become obsolete (Doukis, 1989). Additional methods and models will be required in DSS but such expansion significantly increases the system's complexity and thus makes it even more difficult to use. Where greater complexity is unavoidable, it may be managed with additional "expert/intelligent" components in the DSS (El-Najdawi and Stylianou, 1993).

3.2. Reasoning in DSS

There are two basic approaches to incorporating reasoning capabilities into support systems: the *DSS-oriented* and the *ES-oriented*. Both approaches are technology driven. In the first, AI technologies are used to augment and enhance conventional DSS with expert knowledge and reasoning capability. Alternatively, DSS models and algorithms can be embedded in ES used for decision analysis and support. Both approaches aim at the development of intelligent DSS also known as knowledge-based DSS or Expert Support Systems. These approaches can be successfully applied to upgrade and enrich an existing DSS or to develop a DSS for a specific problem. Their limitation lies in utilizing new technologies to address problems within the constraints of existing DDS.

Traditionally, the role of DSS and the associated design issues have been discussed within a "process theory approach" presenting a series of activities as a sequence over time (Mohr, 1982). These are descriptive representations of the decision process. The most prominent are based on Simon's phase model and its extensions which have been used to determine the support required for activities performed in one or more decision phases (Sprague and Carlson, 1982; Turban, 1993). The elaboration of Simon's model by Mintzberg and his colleagues (1976) coupled with Mintzberg's identification of managers' cognitive tasks (1975) guided Brookes (1985) in his presentation of a framework for DSS development. Until recently, however, these descriptive models were mainly used within the *supporting perspective* corresponding to activities expected to be performed on the instrumental level. Such models formed the basis for the selection of quantitative methods, the mode of access to data-bases and mechanisms of data consolidation and presentation. Developments in cognitive science and artificial intelligence allow more direct support of agents' information processing activities, that is their cognitive efforts. This suggests a *cognitive perspective* for the development of cognitive support systems.

In the late 1950s McCarthy introduced the concept of an "advice taker" as a system that, when given a goal, could perform autonomous actions leading to its realization, seeking - if it reached a dead end - advice from the user. Most DSS communicate with the user on the instrumental but not the cognitive level. This is one of the main sources of users' difficulties in using systems. Conventional DSS are developed more with the decision methods and data processing abilities of a computer in mind than the user's intellectual faculties. Now the effort is to make a support system that interacts on the cognitive level. Such systems facilitate the development of

qualitative representations, as, for example, COPE (Eden, 1992) and are also able to construct complementary representations of subproblems.

Cognitive support systems, with or without the user's intervention, build representations, select appropriate formal models, organize these often heterogeneous models into a composite structure, retrieve relevant information and determine the order of processing. These activities are driven by the needs level including the need to help and to communicate. This requires the ability to match the system's generic knowledge about needs, values and motivations with the user's current needs and values. It also requires the ability for the system to recall all its actions and explain their meaning.

The cognitive perspective on the development and use of support systems is a user driven perspective that focuses on the information processing efforts of the user. Qualitative representation and procedural and declarative knowledge becomes primary while the quantitative aspects of the problem and solution algorithms are secondary. The systems' reasoning is based on two forms of rationality (von Winterfeldt and Edwards, 1986): rationality of inference and instrumental rationality. Rationality of inference implies that the formal model (a set of axioms and a set of inference rules) used by a support system is sound, that is, all derived statements are true when the assumed set of axioms and statements are true. Instrumental rationality means that if the formal model uses supporting models (for example, models to determine the value of parameters) then it selects appropriate models, those which are applicable in a particular context and which effectively use the available information.

3.3. Support of fundamental requirements

The shift in focus from the supporting to cognitive level allows the system designer to consider the basic requirements of decision makers. There are two fundamental requirements of decision makers that any support system needs to address: *simplicity* and *consistency* (Hill et al., 1982, p. 62-66). Simplicity is required to select and organize information. Human beings, whether operating as individuals or in groups, can access only a limited amount of information at one time. As Simon (1960) argues, decision makers bound rationality to derive a structured, limited depiction of the decision which includes its critical components. Thus the presentation of the problem within the DSS must be driven by the cognitive capabilities of the user to provide information that is critical to the problem. At the same time the DSS should perform as detailed and comprehensive a computation as possible with the results communicated concisely and succinctly. All additional queries from the user should be treated in a similar manner unless the user wants to enter into a discourse with the system and understand its reasoning leading to a particular recommendation. In short, the system must present a simplified version of the problem to the user while maintaining its underlying complexity (or indeed increasing it by adding additional interactions) for access during the decision process.

Consistency in decision making and support has three dimensions. The first dimension includes *internal consistency* of representations and consistent application of solution procedures leading to a decision alternative. This is an obvious requirement and a prerequisite for simplicity. However, it may be difficult to achieve if knowledge is incomplete, the models are heterogeneous or the sequence of procedures is executed more than once. Different structures of the same model elements may result in contrasting representations of the overall problem. A simple change in the sequencing of procedures or accessing of stacks of data may produce different results. Decisions concerning the structuring and implementation of the model are often made at a low level of system execution and consequently may be difficult to explain to the user. For example, the recommendation of an expert system depends on the order in which data are used but the sequencing of data may have little in common with the user's understanding of the problem.

Similar difficulties occur in human information processing, where the focus of attention or choice of a particular typology causes some aspects of the problem to be ignored. The user expects bias removal and representational consistency from a system. While in general this cannot be achieved, low level decisions made by a computer system need to be known to the DSS which has to be able to assess and interpret their impact on higher level decisions and actions.

The second dimension is *needs-outcomes consistency*. The relationship between the decision maker's needs and decision outcomes is the cornerstone of decision analysis. Typically, it involves preference elicitation, alternative comparison or determination of a measure of decision quality (for example, utility, achievement or value functions). While there are numerous approaches for the specification and formal representation of needs, their explanatory power has been questioned since they cannot prespecify values attached to decision outcomes (Pettit, 1978; Tversky, 1975). The contribution of decision theory, however, is that it can provide important elements of support at the instrumental level with its methods subordinated to the agent's cognitive representations. This implies that on the cognitive level decisions are made as to the necessary assumptions, the methods to be used and how recommendations are to be interpreted.

The third dimension of consistency involves the relationship between different decision problems. This is *inter-decisional consistency* and it reflects the expertise and history of the decision maker and the need to maintain consistency among needs and values that are part of the decision maker's personal context (Hill et al., 1982; Newcomb, 1953). This issue has been largely unconsidered in decision theory and DSS because the focus remains on the supporting and not the cognitive level. With the shift of support to the cognitive level it becomes more important that the system be able to detect needs based differences in the user's requests and requirements.

3.4. Conflict resolution

Inter-decisional consistency, a critical issue in sequential decisions such as negotiations, is discussed in the following sections. Another issue typically associated with negotiation but present in most individual decisions is *conflict*. Although different conflict situations appear in interpersonal and intrapersonal decisions, there are also similarities, some of which have been extensively considered in psychology, decision theory and decision support (Hill et al., 1982; Levi, 1986; Levin, 1936; French, 1988).

Conflict, like consistency, may be considered at several levels which correspond to the transformation of needs and values into specific objectives, aspirations and goals, introduction of these into models, and the determination, comparison and choice of alternatives. No decision can satisfy all the user's needs, so conflict at the needs level involves their selection and prioritization. Realization of a decision opportunity during the intelligence phase involves, first of all, an opportunity to address a need. At this stage little processing is done and any conflict resolution among needs may be temporary and subject to revision (this possibility may lie behind rank reversal or an apparently irrational preference structure).

It is often necessary and advisable to transform needs and values into a formal quantitative representations. This allows their measurement, comparison, verification of preferences and trade-offs, the use of choice mechanisms, and determination of the level of needs satisfaction yielded by decision outcomes. It is usually impossible to assign one measure to each need and obtain an equivalence relationship between a need and its measure. A conflict then arises as to which needs are formalized and which are not, what measures are selected, and what assumptions are made that reflect the attitude of the decision maker represented in the objectives, aspirations and goals. This conflict reinforces the tentative and supporting role of decision methods that assume the independence of objectives.

It has been argued that decision makers solve problems and evaluate solutions using both holistic and analytic (systemic) perspectives (Mayer, 1992). DSS typically support the analytic perspective; the specification of needs and preferences, the specification of constraints and bounds and the choice mechanisms defined on objectives, goals and preferences assume this perspective. For the assessment of alternatives and their comparison the holistic perspective may be used. The two perspectives may be in conflict in alternative comparisons. Moreover, it is also possible that different alternatives are evaluated from different perspectives.

Support to resolve conflict arising from the two perspectives may be sought in three complementary ways. One, as mentioned earlier, is through maintaining similarity in the representations created by the user and the system, that is support of the cognitive level. Another is the presentation of the overall problem structure in a way that gives the user the ability to see the whole representation, while taking into account the simplicity requirement. The third way is

to support progressive modification of qualitative representations of the problem. Such modification is the primary approach of the holistic perspective (Duncker, 1945; Mayer, 1989).

Other types of conflict may also appear, including conflict between alternative partial representations, their organization, methods and procedures. These conflicts need to be resolved. A properly designed DSS, in contrast to the user, is capable of noting them and conducting analyses of alternative resolutions.

4. Negotiations

4.1. Interdependency

Negotiation is a decision process in which two or more agents make individual decisions - formulate compromise proposals. The proposals are communicated to other agents. Upon receiving a counter proposal, a new proposal is determined. The process continues until either an agreement or a deadlock is reached.

The purpose of individual decisions is twofold:

- to determine reactions of other agents and obtain their responses; and
- to indicate the outcomes that the agent would like to achieve.

The agent is unable to obtain these outcomes without agreement of the other agents. The agents' interdependence requires that the agent accommodates at least some of the needs of others and makes concessions.

Negotiation has several important characteristics that contribute to its complexity and to the difficulties inherent in developing adequate representations of the process. These include the involvement of two or more decision making agents. Each agent has specific needs and requirements. The agents may also differ in their perception of the problem and have different understandings of its solution. They negotiate because they are interdependent and no one can implement a chosen solution without the acquiessence of the other parties to the process.

Differences between agents and their interdependence introduce the need for *interaction*. Agents must communicate their needs and the resulting solution requirements and translate the information obtained from others into their own system of needs. The difficulty is that messages are often coded because the agents do not want to disclose their true needs. Thus, we have a new level of complexity[1]. In addition to the difficulties with one's own specification of needs and their transformation into goals and objectives, the agent faces the additional problem

[1] This compleixty may be further compounded by other factors such as, emotion (e.g. Howard, 1994), culture (e.g. Adler and Graham, 1989) and style (Ali, 1993).

of transforming them into messages. At the same time, the agent needs to interpret messages from others in an attempt to determine their true needs and the impact of potential messages on the agent's situation.

Research on negotiation often assumes that disagreement, conflict or contrasting perspectives provide the underlying reason for negotiations. Interdependence, however, rather than conflict distinguishes negotiation from other forms of decision making (Lewicki and Litterer, 1985). Any conflict in negotiations may be apparent or real. The agents may be in conflict over goals and objectives. To resolve such a conflict they may accept the conflicting goals and objectives of the others and concentrate on those they share and/or they may focus on the degree of their needs fulfillment. An agent, knowing that some needs may not be achieved because of the conflict, accepts concession making, otherwise the more important needs would not be achieved at all (including the need to achieve a compromise). We assume that the agents are willing to cooperate and interact to achieve a compromise.[2]

This process aims at identifying differences and similarities in the agents' positions and at reducing areas of disagreement. This can be achieved through expanding the sets of acceptable alternatives (Kersten, 1988; Shakun, 1985). Alternatively or simultaneously the agents may attempt to replace the contentious issues with new ones that underlie jointly "profitable" outcomes. This involves modification of the problem and introduces another difficulty and potential conflict in the selection of competing new issues and the interpretation of their relevance to the agent's needs.

4.2. Interpretations

An agent never fully knows the assumptions, preferences, goals and limitations of the others. The process of message exchange enables the agent to learn more about the others and often about the problem itself. This means that the agent's understanding of the problem, its solutions and their implications may change. The assumption, frequently implicit in systems of negotiation support, that the "world" consisting of the agents, their problems, the environment (including the agents' constituencies) can be frozen at any point in time is unrealistic. If the often criticized "fixed-pie assumption" is not made, then the "enlargement of the pie" leads to a modification of the negotiation problem.

An additional type of conflict is introduced with the *interpretation* of the others' behaviour. There are many negotiating tactics and strategies that depend on the perception of the opponent (Wall, 1985). This perception will normally be formed before the actual negotiations but it is

[2] We exclude from our discussion cases in which parties are forced by other parties, by legal or contractual requirements or by strategic considerations to enter negotiation without any intention of reaching a compromise.

refined and modified during the process through interpretation of communication. Because the underlying reasons for a particular message are never known with certainty, the agent faces a choice in selecting an interpretation. This has an impact on the agent's proposal and the subsequent reactions of the others.

One of the important roles for interpretation is to determine if and to what degree a concession has been made. Individual decisions are driven by needs and their representation in terms of objectives, goals and preferences. In negotiation a decision is then transformed into a message. At this level, the chosen decision (proposal) may be modified and expanded; comments, rationales and explanations are added.

Concessions can be assessed from two viewpoints: whether the author of the message decreased achievement of her needs to some degree and whether the new proposal allows the recipient of the message to fulfill his needs to a higher degree. Because of the transformations between needs and their representation, problem representation, problem solution and message interpretation is difficult and uncertain. Situations occur where an agent's proposal may be considered by the others as a concession when it is not or where the agent makes a concession but the others view it is as a hardening of her position (reverse concession), (Kersten et al., 1991; Raiffa, 1982).

4.3. Strategic interactions

The sequential nature of negotiation is significant because it demands dynamic behaviour by the agents and introduces the possibility of using different protocols and agendas. Because negotiations may take a long time, the environment in which the negotiation takes place may also undergo significant changes.

The complexity of negotiation often requires that the agents resort to "sequential negotiations" in which issues are discussed one at a time. This introduces difficulty in maintaining consistency in the evaluation of proposals, especially if new issues are being introduced (Lewicki and Litterer, 1985). At the other end of the spectrum, negotiation involving the simultaneous consideration of all issues imposes such cognitive and computational requirements that agents may not be able to meet them.

One of the important features of sequential decision processes is that decisions are made to enable an agent to make subsequent decisions and to prepare the ground for future actions. This introduces strategic interaction which requires the interpretation of others' needs and situations. An agent makes decisions contingent upon her estimates of others' actions (Young, 1975). The principal question in making the interpretation and assessment of others' behaviour is whether this behaviour should always be considered as rational or taken at face value. Raiffa (1982) suggests the prescriptive/descriptive approach. The interpreting agent represents her

problem using prescriptive methods based on the rationality axioms and uses facts describing other agents' behaviour with no reference to their rationality.

Schelling (1984, p. 204-205) presents a strong argument that agents must assume that others are rational. However, his understanding of rationality is not based on the rationality axioms. Rather, it is based on the assumption that the agents know their own needs and values, are aware of the alternatives, use the values and alternatives to evaluate and choose a decision, and are able to assume the others' viewpoint (see also Fisher, Kopelman and Schneider, 1994; Ury, 1993). Schelling's argument seems compelling and appropriate within the perspective presented here. As Nierenberg (1973, p. 40) points out, "behaviour should not be referred to as irrational until the assumptions and premises upon which it is based are known".

The critical question in strategic interaction and preparation of proposals for the agent is not whether an opponent is rational according to any particular definition, but to what extent her choices are determined by the situation she is in and to what extent the agent can determine her values. The difficulty is multiplied in that the opponent makes her decisions contingent upon her assessment of the agent.

The answer to this question allows the agent to consider the *stability* of his compromise proposal. There is a large body of research on stability in interpersonal decisions and we return to this issue in the next section. The point we make here is that in most situations stability can be assessed only with uncertainty and that the basis for categorizing alternatives may change during the process.

Another important issue is the relevance of the process of negotiation. While it follows from the above that the process of forming and exchanging proposals, interpreting behaviour and modifying the problem is essential, many researchers limit their interest to the outcomes. For example, it is typical for game theory to ignore the process and assume that the agent is concerned only with outcomes. In many real life situations neither the assumptions nor the consequences of such an approach can be sustained. The agent's needs and values include confidence, exchange of ideas and maintenance or increase of self-esteem which may not be achieved without interactions leading to a better understanding of the other agents. Negotiators' attempts to concentrate solely on outcomes must fail (Lewicki and Litterer, 1985). It follows that support which concentrates only on outcomes will likely support only failure.

4.4. Assumptions

From the many other features that characterize negotiation we consider here those upon which all other constructs are built. They are assumptions and beliefs. The difficulty is that many of the assumptions which form the basis for decision making and interpretation are hidden and made unconsciously. The computational effort required to enumerate and analyze all the as-

sumptions underlying the agent's behaviour would make any action impossible and any attempt to do so would result in endless contemplation. On the other hand the significance of the assumptions and the fact that many of them, when analyzed, are at odds with the agent's own perception and understanding requires an effort be made to identify and verify most critical assumptions.

Nierenberg (1973) proposes three categories of assumptions that reflect one's categorization of the world. Assumptions about the agent's *intentional* self belong to the first category. These are assumptions about needs and values and their ordering. They also include assumptions about the relationship between the decision opportunity and the possibility of needs fulfillment as well as the ability (negative or positive) of the other agents to contribute to their fulfillment. The second category includes assumptions about the other agent's *intentional* self. The third category deals with assumptions about the *extensional* world, those concerning the environment in which the agent operates. The frequently unverified basis for many assumptions coupled with the learning aspects of negotiation, require that assumptions need to be verified on an ongoing basis. This remains a neglected but important area in negotiation support which becomes central within a cognitive approach.

5. Negotiation representation and support

5.1. Outcomes and predictions

Research on the application of information technologies, formal methods, including decision analysis and, more recently, artificial intelligence, to negotiation and negotiation support is extensive. Many negotiators use computer models to prepare and analyze their own and their opponents' proposals. Computer systems are used to determine financial implications, conduct market analysis, simulate implications of proposals on the ecological system, or display and communicate proposals. In most cases these systems provide aid at the individual level and they are used under the assumption that the world in which negotiations occur is static. Because DDS provide what-if and goal-seeking functions they can be used to evaluate the possible responses of an opponent. It is, however, the agent who has to specify the response and translate it into language acceptable to the system. With few exceptions this implies that the agent has to provide the system with a set of numbers representing the opponent's potential reply.

We have observed that DDS employ a process theory approach with the aim of supporting one or more phases of a particular framework. This assumes that the agent selects one of her activities and the output requirements. The system then determines the necessary inputs and required processing. Even with the supporting perspective in mind such a design approach to negotiation support is deficient. This is due, in part, to the lack of a comprehensive and uniform

descriptive model of negotiation. As Gulliver (1979, p. 69) observes, “the social science literature is somewhat confused and contradictory about the definition and application of some basic concepts that are used in the study of negotiation”.

Studies on human decision making give insights into cognitive processes, providing a basis for formal decision methods. They form a basis for prescriptions. Descriptive theories of negotiations typically describe components that are relatively fixed; they offer description without a basis for offering prescription (Bazerman and Neale, 1991). Thus they do not offer a baseline for the support.

Neale and Bazerman (1991) argue that a descriptive model of negotiation is useful if it can provide information about decisions facing the agent. Support is designed to give as accurate prediction of the outcomes of negotiations as possible. This is a decision theoretic perspective with heavy emphasis on outcomes. One can argue that a system that can predict outcomes accurately in many situations will not be used. An agent may enter negotiations that for her are novel and difficult but which her opponent conducts so often that he can predict the final outcome with a high degree of accuracy. This knowledge, while helpful, needs to be augmented with his ability to recognize specific needs of the agent, to employ appropriate tactics, and to engage in the process during which the agent gains confidence and/or recognition of the particular situation. As Fisher, Kopelman and Schneider (1994, p. 9) succinctly state, “If we want knowledge in order to improve the world, then predictability is the wrong standard. We need to turn from what is inevitable to those things we can change.”

In a complex and difficult situation a negotiation support system (NSS) may provide an agent with a certain outcome prediction which may actually increase the complexity of the process and lead to deadlock. For one move negotiations such a situation can be reduced to the Newcomb problem (Nozick, 1969) for which one rational solution is to ignore the prediction. In negotiations with multiple moves knowledge about the “final” outcome may cause positions to harden. Reservation levels are replaced with the predicted outcome levels and there are attempts to end the negotiation without due process. Moreover, the prediction would be based on the assumption that the agent continues to negotiate as if it were unknown, but once communicated it may have a significant influence on his behaviour.

Nothwistanding the above we do not claim that predictions generated by a support system are not useful. If these predictions are based on the analysis of the needs of the opponent, the specifics of his situation, and the conditions under which he makes decisions, then they provide significant support.

5.2. Rationality and descriptive support

As Raiffa (1982) demonstrated in his seminal contribution to negotiation research, it is im-

portant to develop accurate descriptions of opponents' needs, constraints, etc. Such descriptions help bridge the gap between prescriptive and descriptive methods (Raiffa, 1982). His suggestion that support through prescriptive methods should be based on an understanding of the opponent's decision processes, rather than the assumption that the other party is rational, has been strongly endorsed through research endeavors of both practical and theoretical relevance (see, for example, Applebaum, 1987; Bazerman and Neale, 1991; Lax and Sebenius, 1986).

Raiffa's suggestion has been stated in terms of prescriptive/descriptive negotiation support. A question that needs to be addressed is whether the support based on prescriptive methods and support based on descriptive methods belong to the same level of support. This question can be also stated in terms of rationality. First, is there only one rationality? If the answer to this question is negative, as is suggested in the previous section, then one may ask whether the rationality underlying prescriptive methods is the same or may be compared with rationalities present in descriptive methods.

There is a wealth of theories and postulates about rationality which have been treated experimentally, indicating that decision makers often violate tenets of rationality. Formal methods are clearly useful in detecting violations of rationality and can help an agent to analyze their sources. On the other hand, decision methods can detect irrationalities in rational behaviours. Rationality can be reduced to five axioms but at the cost of rejecting certain forms or types of rationality. In negotiations agents establish relationships, represent others, belong to organizations and have to consider and balance individual, contextual, procedural, organizational and other rationalities (Cohen et al., 1972; Lindblom, 1970). Rationality evolves, is adaptive and may take forms that are not explicitly retrievable - particularly in interpersonal relations (Nozick, 1993, March, 1988). Agents would be irrational if they did not use their background knowledge, common sense, beliefs and intuition but they also would be irrational if they did not verify rationalities based on these constructs (Nozick, 1993; Simon, 1991; Simon et al., 1988).

The key to Raiffa's thesis that is relevant to our discussion and in accordance with postulates formed by Gulliver (1979), Nierenberg (1987) and Schelling (1984), is the focus on understanding rathre than on a narrow concept of rationality. As Nozick (1993, p. 178) states in the conclusion of his significant book, "We would not then expect rationality to set out to prove that others are rational or be able to do so; this is something it assumes and works in order to get on to other business."

Understanding requires identification of needs, the specification of a situation and the abilities of the agent. It can be achieved at the cognitive level, is based on descriptions of behaviour and it may provide prescriptive recommendations. If a negotiation support system can help an agent

to understand her opponent then the agent or the system can specify recommendations. The need for understanding is not limited to the opponent. Research on individual and group decisions indicate that the agent may benefit from support in gaining insights into her own reasoning process, assumptions and beliefs (Ury, 1993). Thus, we need descriptive representations of both the agent and her opponent; to aid the cognitive efforts *descriptive/descriptive* support is required. The descriptions, however, need to include interpretation and encompass both the surface level (communication) and the reasoning and needs levels.

Descriptive representations are developed to determine the rules of rationality that underlie and explain agents' behaviour and positions. A cognitive system may attempt to organize and consolidate different representations in search of consistency and its violations. Through reasoning on these normally incomplete representations, it may identify discontinuities and modalities. These activities lead to the formulation of specific questions necessary for understanding the agent herself as well as her opponent. If the system can access models based on behavioural theories which incorporate the experiences and histories of other agents, it may be capable of suggesting why a particular behaviour occurs. It then may generate prescriptions as to what could and should be done.

5.3. Two level organization of support system

The point we wish to make is that at the cognitive level understanding and prescriptions are achieved only through collecting descriptions, reasoning about them and drawing on experiential and theoretical knowledge. Because the notion of rationality is prescriptive (von Winterfelds and Edwards, 1986), by uncovering the rules of rationality used by an agent, prescriptions can be generated. There are numerous methods and technologies which can be useful for such support but they need to be integrated and to take account of behavioral theories. Most importantly, they need to be placed in a framework which is in correspondence with the agent's cognitive framework. This allows for a congruence of methods and technologies relevant the agent's particular needs and abilities.

In the decision theory framework prescriptive methods are used to help the agent and the system reduce computational complexity and to help identify local inconsistencies and discontinuities. Game theory, multi-attribute utility theory, aspiration theory, theories of bargaining and other formal theories of decision making and negotiations have a significant role in negotiation support. They can be used to evaluate negotiating tactics, determine relationships between requirements and aspirations and feasible alternatives, evaluate the stability of alternative proposals, etc. Whatever the range of methods available through the system, their selection of methods and use should be controlled by the support system which also interprets the results.

The selection of appropriate methods, their organization to represent different aspects of the

problem and agents, and the organization of processing is determined by the needs and context which are established at the cognitive level. These methods support the computation required to build descriptions and determine their implications for understanding and reasoning. They, together with other methods, for example searching and analyzing data bases or building interfaces, belong to the instrumental level.

Subordination of the instrumental level to the cognitive level can be viewed as an implementation of the researchers' postulating conversation between the decision maker and the analyst and among human and artificial agents (see for example, Holtzman, 1989, Winograd and Flores, 1986).

The two-level organization of a negotiation support system is based on the levels of articulation. Each level needs to be further decomposed in an attempt to design such a system. Examples for such decomposition are given in the literature on DSS, ES, DAI, and cooperating systems (Moyse and Elsom-Cook, 1992; Rosenschein and Zlotkin, 1994).

One implication of the two level organization is that holistic and analytic perspectives may be subsumed in a single negotiation support system. This requires the system to acquire knowledge that is compatible and complementary to the user's understanding of herself, the situation and the problem. This implies that the system must have the ability to develop contrasting descriptive representations and to acquire the user's representation. Contrasting representations can be developed using similar and previously solved cases, adapting theoretical postulates to the situation at hand, asking the agent to choose components of representations that are then combined and analyzing a number of previous decision problems solved by the user.

The task of designing such a system becomes even more difficult if the system is to be utilized by more than one user, if it is designed to be used by a group or if it is designed to mediate between negotiating agents. Since the representations of even simple problems vary from user to user and over time, a system with multiple simultaneous or sequential users should be capable of supporting multiple problem representations and multiple rationalities. (This is exactly what a skilled mediator does when he represents one agent's highest priority to the opposing agent as but one issue among many.) While the users may require that the system match their representations even when it is inappropriate, the main role of the system is to provide for decision makers, as von Winterfeldt and Edwards (1986) suggest, both rationality of inference and instrumental rationality.

In Section 2.1, we said that the agent articulates a negotiation problem on three levels: needs, cognition and supporting. The difference between formulation of representations by a system and by an agent is twofold: the system does not have its own needs but uses needs specified by the agent. The system uses rational inferencing while the agent may use intuition and beliefs.

6. Integration

6.1. A view of decisions and decision support

In the preceding sections we have attempted to understand the current state of decision support thinking from the view of the user. An overview of the discussion given in Sections 2 - 5 is given in Fig. 3.

Decision analytic and support methods aim at the development of representations of measurable problems. Because of the difficulty in building appropriate representations that conform to the rationality axioms, decision theorists posit an intermediary between the system and the decision maker. In short, we propose a cognitive support system which takes on the role of such an intermediary.

For most current approaches the focus is on a relatively inflexible system, built on decision theoretic principles, which is oriented toward problems in a single area. While this approach may suffice for static, well-defined problems, it is insufficient when applied to the dynamic problem of negotiation support. The most important limitation of current approaches is the assumption that problems have requirements independent of the agent. It is our view that, while a problem may impose constraints, only the agent may have requirements, requirements which reflect her needs and which are mediated by her abilities.

We propose that the needs and abilities of the decision maker are the starting point for thinking about decision support. This implies that any support system must react to and support the cognitive processes of the decision maker. The decision maker constructs a calculus of needs based on her understanding of the world, including other agents, the context and their history. As the decision process unfolds, in negotiations as other agents react, the world is altered and the cognitive map used by the decision maker changes. An effective negotiation support system must be able to reflect these changes and do so without having to reconstruct the whole system

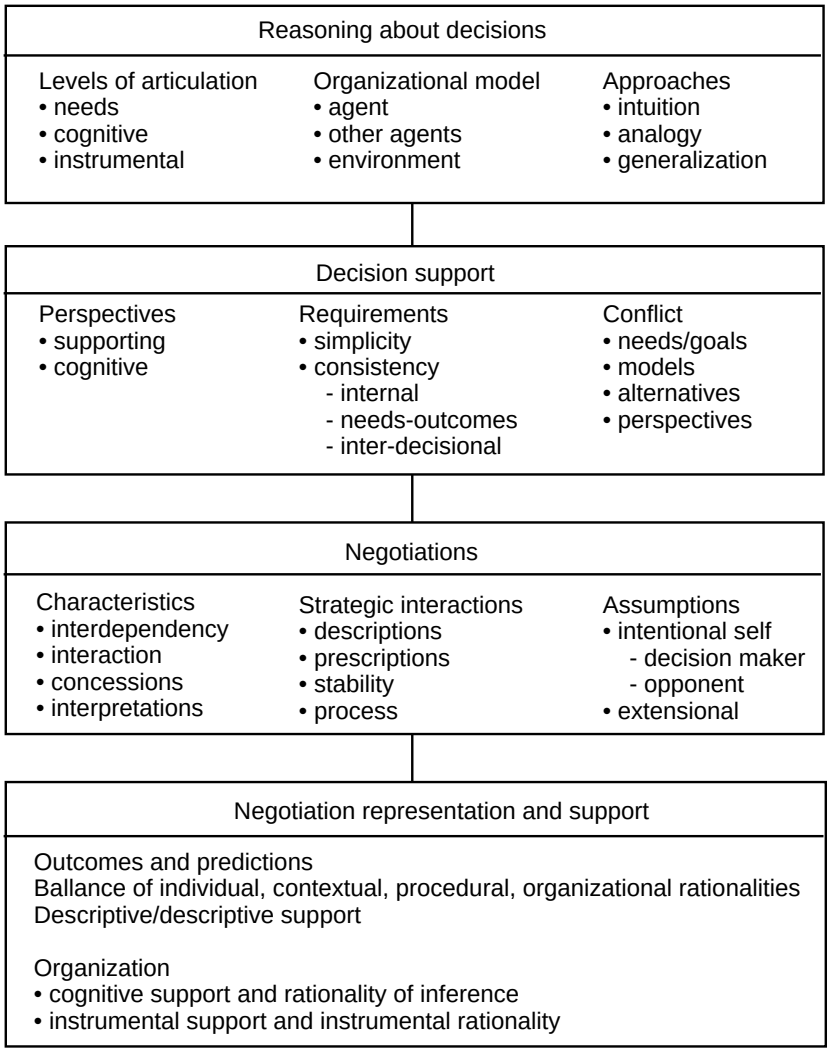

Figure 3. Issues in decision making and support

One indispensable requirement to such a system is flexibility. It must be flexible enough to accommodate the shifts in the user's appreciation of the situation. It must also be flexible enough to utilize tools based on decision theoretic approaches as well as other tools derived from behavioural theories. At the same time the system must be consistent in use and simple enough for the user to readily understand its high level operation. This means that the changes allowed by the system must be traceable. The agent must be able to relate her changing perception of the relation of her needs to the situation through the system itself.

6.2. Restructurable modelling

Restructurable modelling is a framework used for the representation of sequential processes involving interacting entities, the support of decision makers and the design of autonomous artificial agents involved in sequential decisions. The framework is part of an ongoing research program; its specific mechanisms and methods are implemented in the Negoplan system. Both the framework and the system are being continuously enhanced and expanded on the basis of

experiments and applications. A formal account of the present state of this application of restructurable modelling is given in Kersten and Szpakowicz (1994, 1990). Here we discuss only the main aspects of restructurable modelling and the reasons for its use as a platform for the development of cognitive support systems.

Restructurable modelling is based on the organizational model of decision making discussed in Section 2.2. Thus, the representation of the agent's problem is distinguished from the problems of other agents and from the environment. The entities are represented separately so that they may interact and have their own needs and limitations. From work already done with Negoplan it is clear that a large variety of both problem structures and situations can be expressed by statements with logical values and that logical reasoning is the central mechanism for solving problems. (While two-value logic is used in the current Negoplan implementation of restructurable modelling, the increase of the system's expressive powers by using multivalue logics needs to be determined.)

The Negoplan system is used to develop *sequences of possible situations* in which the decision maker, the other agents and the environment may find themselves. Actions and reactions of the represented entities to each other or to changes in the environment cause them to move from one situation to another.

The primary agent's representation corresponds to the cognitive level of articulation (Section 2.1.). The focus is on the structural and qualitative aspects of the problem. These aspects include the goals (needs specified by the agent in terms of symbols), subgoals and those elements of the situation that are under the agent's control. Decision problems are assumed to be decomposable and can be represented as a directed acyclic graph with the nodes as predicates. A constraint propagation method is used to determine a problem representation that is equivalent to one qualitative problem solution. The solution is a subgraph of the problem representation. The selection of a particular solution is achieved through an application of decision rules, quantitative choice mechanisms (e.g., a value function), the user's direct choice or their combination.

Predicates describing a problem or a situation may include quantitative and qualitative parameters. Their values are determined by the complementary models associated with them. The process of defining a qualitative solution also involves specification of the parameter values. Similarly, parameters included in the predicates describe states of the environment and the situations of the other agents; their requirements and limitations are determined with the complementary models. The choice and application of complementary models is context dependent; evaluation on the cognitive level dictates the use of models available at the instrumental level. A model is used if the reasoning mechanisms require the determination of a logical value for the predicate with which this model is associated. This allows for explanation

by the system of why a model has been used and what role it played in the solution.[3]

For a given solution some of the predicates representing the problem are not valuated. These are *flexible* aspects or issues of the problem in the sense that their achievement or realization is not required to achieve the needs of the agent represented as goals and criteria (Kersten and Szpakowicz, 1990). If flexible aspects are present, the agent may expand the current solution. In negotiation, this expansion corresponds to adding "bargaining chips" to the offer. The predicates describing problem aspects which are significant for the selected goals and criteria of the agent are *inflexible* problem elements. An excellent example of a flexible issue can be found in the case of AMPO vs. City (Raiffa, 1982).

A decision alternative (a problem solution augmented with flexible elements) that has been selected by the agent is implemented. When this implementation is communicated to the other entities it elicits reactions. These entities may make their own independent decisions which have an impact on the situation of the agent. When the Negoplan system is used for simulation, the actions and reactions of the other agents and the environment are determined within the system by meta-rules; logical statements with annotated and valuated predicates.[4] The annotation describes the entity that selected the predicate and gave its value (including parameter values). Together, reactions and responses of the other entities and their actions which are independent of the agent's decision define the new situation including decision outcomes. This change may result in another iteration of the process or its termination (in negotiation termination would be acceptance of the opponent's proposal or a breakdown of the process).

The current situation is interpreted by a set of meta-rules; logical statements with annotated and valuated predicates (metafacts). The annotation describes the entity that selected the predicate and provided its value (including parameter values). In negotiation this allows us to include counter-proposals, which are decision outcomes, and associate them with elements of the agent's own proposals. Interpretation may be done automatically or by the user who selects appropriate responses. In addition, the selection mechanism allows the user to introduce elements or parameter values that are not associated with a particular context.

Models may be linked to meta-rules and used to determine the state of the environment or for a more detailed analysis and interpretation of the other entities' actions. These models can be formal models derived from behavioural theories which are used to collect the history of the negotiation process and assess the opponent's behaviour and its underlying reasons.

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[3] The current version of Negoplan does not provide explanatory facilities.

[4] Alternatively, these values may be entered by the supported agent or read by the system from messages that it receives.

Within the restructurable modelling framework several different mechanisms are proposed to determine the supported agent's reaction to the new situation caused by her proposal and other entities' reactions and exogenous actions. The four *modification mechanisms* in increasing order of their impact on the needs level are: reorganization, adjustment, revision and restructuring.

Reorganization involves only the flexible elements of the agent's proposal (position) so that their valuations and/or their parameter values are changed in response to the requirements imposed by the new situation. This modification mechanism does not require any change in the agent's goals and criteria thus her ability to fulfill her own needs remains unchanged. In negotiation, reorganization is a tactical mechanism invoked when the agent is able to introduce issues that do not have any impact on the achievement of her needs.

Adjustment is invoked if reorganization is impossible or if the new situation requires a more substantial modification in the agent's position. This mechanism does not change the current problem structure but operates on the existing values of the problem parameters. The change in the parameter values can be determined by complementary models or metarules (for example, metarules describing changes in aspiration levels). Because adjustment is a second order mechanism its application may involve reorganization, that is changes in the valuations of flexible elements of the structure.

Models or rules used for adjustment are applied only within the context defined by the entities' situation and the explicit assumptions representing the agent's willingness or ability to change selected parameter values. This restricts the use of the adjustment mechanisms to situations which do not require changes in the qualitative aspects of the problem.

The third type of modification mechanism involves *revision* of the structure of the agent's problem representation. While the structure of the problem remains unchanged this mechanism attempts to determine a different problem solution and a corresponding structure. In effect, this causes some of the flexible elements to become inflexible and at least one inflexible element to become flexible. Revision means that some of the goals and criteria may no longer be achieved. In addition the parameter values are recomputed.

The last modification mechanism is *restructuring*. It is invoked when the decision outcomes and actions of other entities make the representation of the previous problem inadequate for the current situation. Restructuring involves problem transformation, that is replacement, addition or deletion of some elements of the problem structure. The introduction of new elements may cause new complementary models to be introduced or the assumptions of the existing models to be changed.

Each of the four modification mechanisms allow for reactions of a different scope by the agent.

While they introduce progressively more significant changes in the problem representation, it is not obvious that they should always be applied in the order given above. One possibility is that the agent selects a modification mechanism. This option may, however, impose requirements that are too severe for the user. Another possibility, partially implemented in Negoplan, is to use the current situation for mechanism selection. The difficulty is that this is a purely reactive move with no strategic considerations. These considerations, augmented with a theory-based analysis of the opponent's behaviour, need to be included in the approach.

An overview of the Negoplan system indicating the relationships between problem representation, modification mechanisms and metafacts is given in Fig. 4.

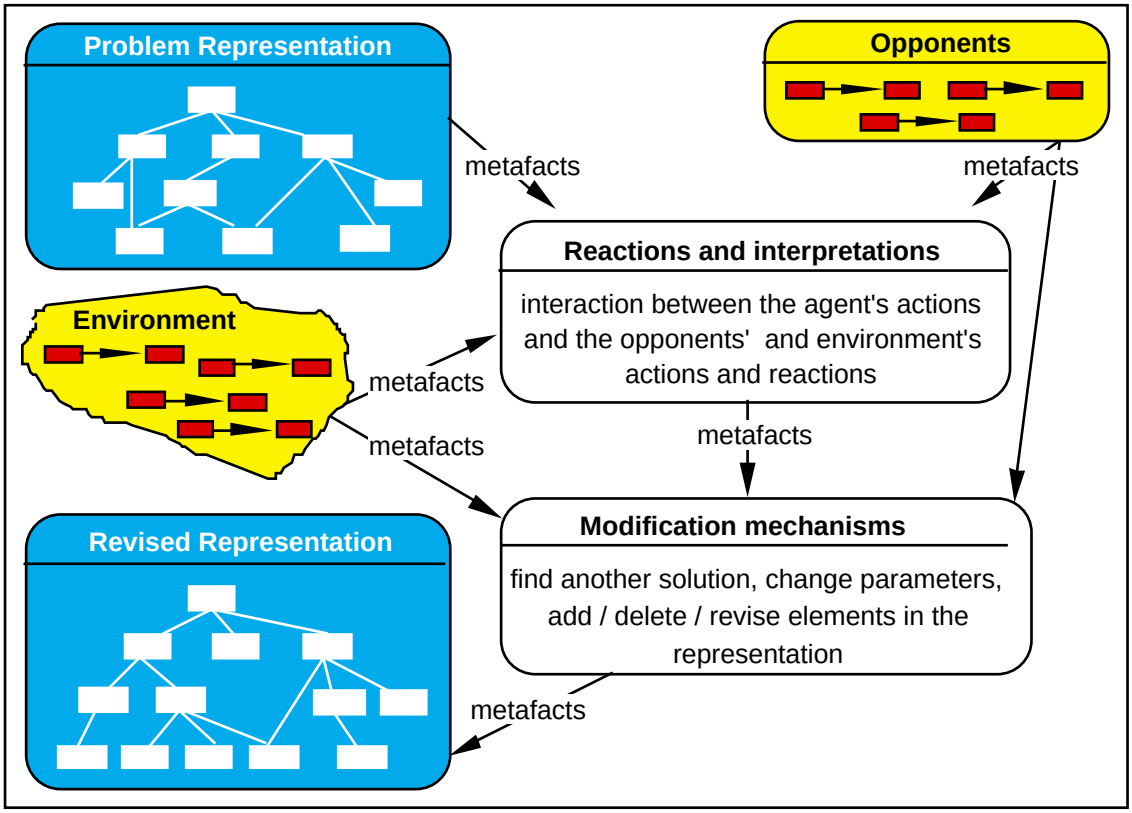

Figure 4. An overview of Negoplan mechanisms

6.3. Experiences with Negoplan

Negoplan has been implemented in Prolog. It runs on Sun workstations and Apple Macintosh. The system can be viewed as a shell with a solution generator, a forward chaining inference engine and a restriction enforcer. Additional mechanisms and procedures have been added for different applications. A simple graphical user interface has been developed for Macintosh and is currently being enhanced with voice, pictures and video.

The evolution of Negoplan is driven by applications and experiments. Initially it was developed for the purpose of negotiation support. Several experiments were conducted including simulation of the Camp David negotiations (Kersten et al., 1988) and inter-organizational negotiation (Koperczak, Matwin and Szpakowicz, 1992). A larger application of the system included the modelling of union/management negotiation for a paper mill company (Matwin et al., 1989) and negotiation with a hostage taker (Kersten and Michalowski, 1989). More recently, Negoplan has been used to analyze foreign investment negotiation (Cray, 1994).

The system's ability to represent various sequential decision processes and the added enhancements has led us to apply Negoplan to sequential decision problems of interacting entities or decision making in dynamic and unknown environments. This includes planning problems (Szpakowicz, Kersten and Koperczak, 1990; Kersten, Ping and Szpakowicz, 1994), distributed artificial intelligence tasks (Kersten and Szpakowicz, 1993), and environmental decision making (Meister and Kersten, 1994). One of the major potential applications is in training and testing diagnostic and treatment skills for medical students and practitioners. Training applications will involve significant enhancements to the interface (Kersten et al., 1994).

Negoplan has proven to be a flexible and expressive research tool that can be applied to real life situations. Because it is based on the models and mechanisms discussed above, it allows for representation and simulation of complex sequential processes involving one or more decision makers. A difficulty typical for knowledge-based systems includes development of the knowledge bases. Because the system attempts to build situation projections this difficulty is more visible than in other such systems.

When Negoplan is applied to complex decisions the number of possible sequences of situations quickly increases. This severely limits the number of alternatives that can be considered by the system and displayed for the user's examination. There are several possible approaches to this problem but in line with our cognitive perspective we are turning more toward behavioral theories of complex decision making for guidance. Analysis of a complex investment decision (Cray, 1994; Kersten, Cray and Szpakowicz, 1994) indicated that decision makers cope with complexity by tackling the alternative decisions sequentially, by recycling through phases and by eliminating or ignoring problem aspects. The incorporation of these insights into the system

are an ongoing project.

Another approach to reduce the number of considered sequences is to introduce high level control mechanisms describing a strategy chosen by the decision maker or closely relating her needs to goals and criteria introduced in the problem representations. An overarching strategic position may well influence not only the acceptability of alternative decisions and the criteria by which they are evaluated but the use of modification mechanisms and complementary models.

7. Conclusions

Raiffa's (1982) introduction of prescriptive/descriptive analysis led to a significant enrichment of negotiation analysis and support. It allowed decision makers to view "significant agents" (stakeholders, opponents, parties) as "intelligent and goal seeking" entities. Behavioral and cognitive studies, and new modelling and support technologies promote a view of the supported party as an intelligent and goal seeking entity. Our argument is that descriptive representations of all the parties can, if analyzed with cognitive and behavioral perspectives, provide rich and valuable prescriptive and predictive support without the unrealistic assumptions underlying the rational agent model. This requires qualitative representation and processing of negotiation problems which cannot be reduced to numerical representation and processing. The latter can be used only for specific aspects of negotiation problems; they must be embodied in in the qualitative representation to enhance their usefulness.

There is an ongoing debate on normative vs. descriptive representation and support and the apparent dichotomy between the two. Our view is that the dichotomy is more apparent than real if the rationality assumptions are considered selectively and are subordinated to the agent's cognitive abilities and her needs. It is also more apparent than real if the biases and deficiencies, extensively discussed in the literature, are considered on the cognitive level and not on the instrumental level. Only then the qualitative problems, raised by Eden (1992), Fisher, Kopelman and Schneider (1994), Sebenius (1992), Ury (1993) and others, can be formally represented, analyzed and their resolution supported.

There are two basic tensions in the cognitive approach that are reflected in the implementation and use of Negoplan. The first is the tension between limiting the problem and expanding the problem. One of the primary insights of the cognitive approach is that every decision maker provides a framework through which world situations and her decisions within it are interpreted. We have argued that to support cognition, and hence effective decision making, the support system must reflect the decision maker's cognitive abilities. The sum of experience and training, embedded in heuristics, symbols, implicit models, theories in use, intuition and rules of thumb provides powerful tools for human decision making. At the same time they

impose limitations because they channel decision processes. To the extent that the system is solely responsive to the user, these limitations restrict possible solutions. The design of mechanisms which introduce facts or interactions in addition to those provided by the user, is a key task for any cognitive support system.

The second tension lies in the application of behavioral models to a system based on formal logic. In theory a cognitive support system is designed to incorporate both either simultaneously or sequentially. Behavioral models and computational models may be accessed within the cognitive framework. In practice their integration may cause difficulties. Formal models tend to be exhaustive, all solutions are equally possible until choices are made. Behavioral models indicate how humans make choices precisely because they cannot be exhaustive. Providing a formal implementation of behavioral theories or vice versa requires further development of the cognitive framework.

Both of these may be seen as creative tensions. The limits of formal reasoning inhibit creativity in solution and process. The descriptive nature of behavioral models precludes rigor and exhaustiveness. The cognitive approach places these in a relationship so that each simultaneously enhances and constrains the other.

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