CSCW: Decision Theory versus Game Theory

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ABSTRACT
The use of decision support systems in firms in order to improve planning as well as ad-hoc decision making recently has experienced a remarkable upsurge.
The formal foundation of such systems usually has been, and in many cases still is, mathematical decision theory. Contrary to this view game theory offers more sophisticated models: In a decision making process there are several decision makers involved, each of them with its own strategy. Instead of a *single optimal choice* of instruments, sets of *equilibrium constellations depending on the equilibrium concepts* chosen are the result of the theoretical investigation of the situation.
The development of Computer Supported Cooperative Work ('CSCW'-) applications has the goal to support working groups. Presenting the basic concepts of CSCW, especially the meaning of cooperation, which will be done in this paper, leads us to the conclusion that the theory of strategic games is the relevant formal approach to the design of such systems.

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INTRODUCTION:

The use of decision support systems in firms, in order to improve planning as well as ad-hoc decision making recently has experienced a remarkable upsurge.

The formal foundation of such systems usually has been, and in many cases still is, mathematical decision theory: A single decision maker has to optimize a set of instrument variables subject to a set of partly stochastic conditions. These conditions partly stem from the specific organizational setting of the firm, partly they are simplifications of market conditions, legal constraints, labor market constraints and the like. The important point is that they can be considered as analogues to laws of nature determining the optimal choice of the decision maker.

Contrary to this view game theory offers more sophisticated models: In a decision making process there are several decision makers involved, each of them with its own strategy. Instead of a *single optimal choice* of instruments, sets of *equilibrium constellations depending on the equilibrium concepts* chosen are the result of the theoretical investigation of the situation.
The development of Computer Supported Cooperative Work ('CSCW'-) applications, a new trend in software engineering, has the goal, to support working groups. Presenting the basic concepts of CSCW, especially the meaning of cooperation leads us to the conclusion that the theory of strategic games is the relevant formal approach to the design of such systems.

Therefore the paper will present briefly the main ideas of decision theory (chapter 1) and game theory (chapter 2). A more detailed discussion on the purpose of CSCW-applications will lead to the analysis what game-theory can offer for the simulation and support of group work (chapter 3).

1. DECISION THEORY:

The framework of decision theory is based on the concept of probability: Indeed it would be easy to choose out of a finite set of possible actions with sure outcome, since the outcomes can be directly compared and the optimal can be determined. All that is needed would be a consistent preference order of the decision maker. What has to be considered as "consistent" has been the topic of a whole branch of microeconomics, namely utility theory.
The results of this research are that today a common view on the notion of so-called "well-behaved" utility functions exists which vice versa is used to define the rationality of decision makers.

Taking into account that real live processes hardly can be described in the mentioned way, but always are characterized by risk, uncertainty and even incomplete information, leads to the necessary inclusion of random processes and expectation formation. As a consequence the easiest possible extension is to combine the utility of each outcome with its expected probability. This single number between 0 and 1 is thought to incorporate all random elements related to the respective outcome.
An interesting question is where these probabilities come from. Keynes (1921) held that there is a strong subjective component in the generation of probabilities used by decision makers. In other words personal experiences and attitudes play a crucial role in the assessment of outcomes' probabilities. This is somehow in contradiction to the main stream view, where the distribution of observed realizations is the starting point for the notion of probability. As far as several independent decision-makers might observe past realizations, directly or indirectly, these probabilities assume a more 'objective' character. In a sense the opposition between these views has been bridged by Bayes, whose concept of learning expresses their mutual dependence: subjective probabilities are learned from objective realizations, where on the other hand it is rather subjective what is considered as objective realization.
In any case it seems to be not trivial to derive probabilities of future events. Therefore in decision-theoretic literature a further distinction concerning the knowledge of the decision-maker is widely used (compare Arrow, 1971): If the probability of an event is known and less than 1 (in other words 'certainty' is excluded), then the respective decision is called 'risky'. If only the distribution function of the event is given, then the respective decision is called 'uncertain', while if even this information is missing the respective decision is made under 'incomplete information'. Learning, as introduced in the last paragraph could lead from incomplete information via uncertainty to risky decision-making.

Once the probability is given[1], the decision process can be presented as follows (compare figure 1):

[1]) For the first formal treatment of the axioms necessary to guarantee the existence of these probabilities see Ramsey (1931).

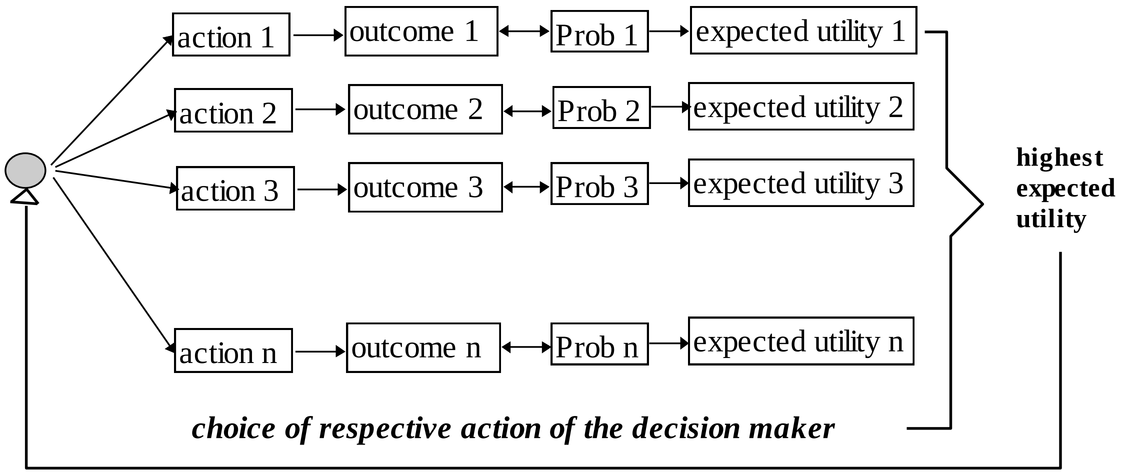

Figure 1: decision-making process based on decision-theory

The decision process is characterized by a decision-maker with a utility function and a set of possible actions. Each action with a certain probability leads to a certain outcome. If outcomes are evaluated by the use of the utility function and are weighted by their respective probabilities, then the decision-maker arrives at a set of expected utilities. Finally the action with the highest expected utility will be chosen. Some authors (e.g. Rhodes, 1993) call the first phase of this decision making process 'decision' and the second phase 'choice': While ‘decision’ includes the steps till the calculation of expected utilities, ‘choice’ refers to the search for an optimum of the latter.

Note that the approach of decision theory assumes that a decision maker is confronted with a certain “state of the world” (Gravelle and Rees, 1981) with random events. This view turns out to be a quite adequate tool to describe situations in which the possible actions are not mutually dependent on actions of other decision makers. Such decision making processes could concern expected consumption with a large number of single consumers: Instead of costly consideration of the involved parties an average probability of their behavior is taken. In many other situations where random natural events like future weather are important, there is no other way than taking expected probabilities[2].

Nevertheless a great deal of decision making situations appears to be a mutual dependency between several decision makers. In other words decisions of a single decision maker influence the decisions of other decision makers and vice versa. Decision theory of course could deal with these situations, too - but not in a sophisticated way. Summarizing, the strategic behavior of an opponent in a single figure like a probability, while it actually could be anticipated clearly neglects available information.
This is exactly the starting point of game theoretic considerations.

[2]) There is, of course, permanent criticism of the mainstream paradigm. Both, on a theoretical level (e.g. Shackle, 1949) and on empirical grounds (e.g. Allais, 1953).

2. GAME THEORY:

Since game theory deals with inter-personal decision making processes, it can be understood as extension of decision theory[3]. Instead of summarizing the influence of other decision-makers in a single probabilities of the respective influenced outcomes, the whole decision processes of the others, including their prospective outcomes is taken into the picture. Figure 2 depicts the new situation.

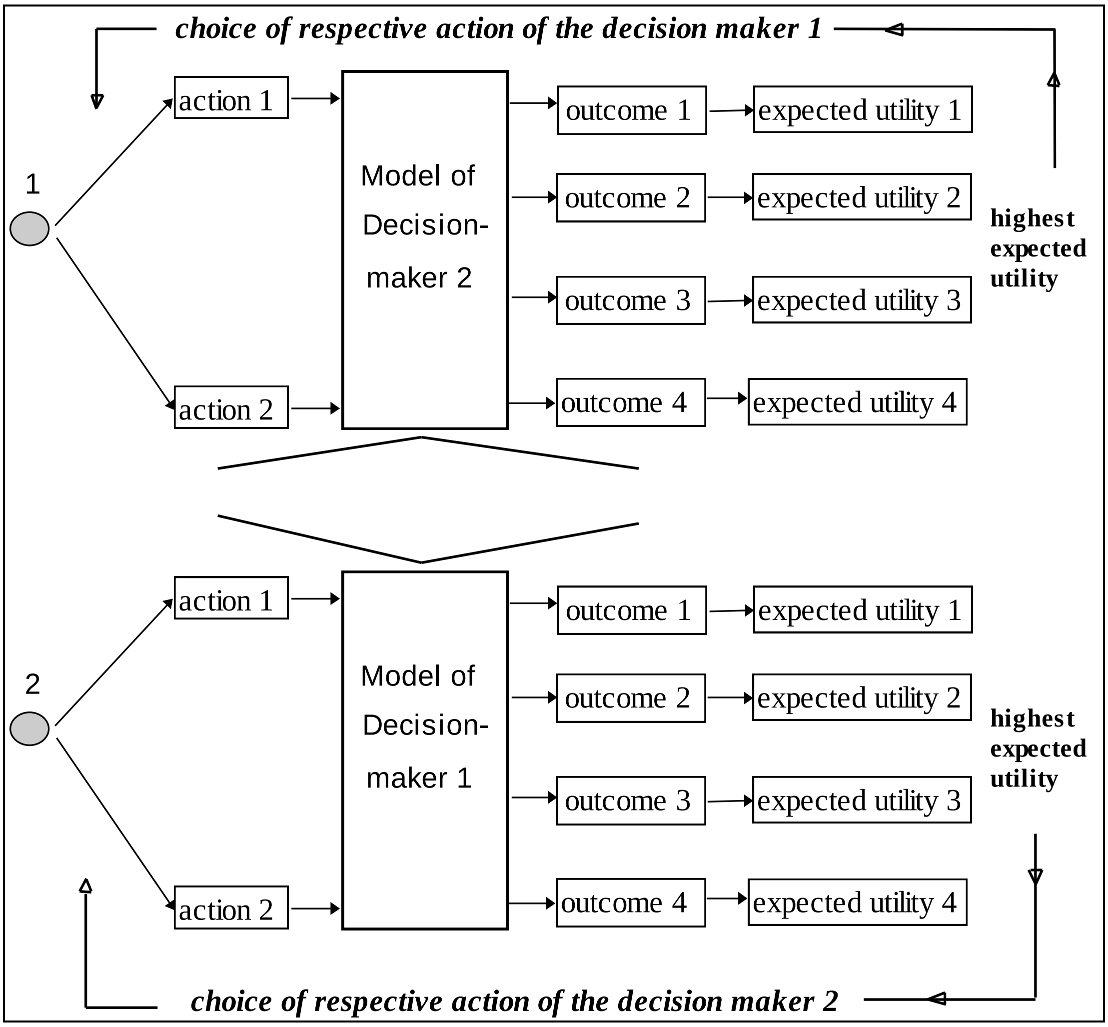

Figure 2: decision-making process based on game-theory

In figure 2 only the interdependence between two decision-makers with two possible actions is shown. Evidently the model of the opponent replaces probabilities. Now the assumptions about the strategic behavior of the other, captured in this model, are the source of uncertainty.

A major advantage of game theoretic formulation is that now the source of uncertainty can be made more explicit by stating what a decision-maker thinks about goals and possibilities of contrahents. As a consequence it must also be made clear what others already have revealed. In other words a time sequence of who chooses when, who

[3]) This evidently is the intention of von Neumann and Morgenstern in their pivotal contribution, which starts with a concise treatment of the utility concept (Neumann and Morgenstern, 1944).

observes whose actions at which point of time must be determined - the rules of the game now are essential for any judgment on possible outcomes. This advantage of game theory over classical decision theory can be called ‘*institutional richness*’.

Another point, closely linked to the one just made, is that even if one chooses a certain equilibrium concept as the one which is most appropriate for the given situation, there still in general will be more than one equilibrium set of actions, or there might be no equilibrium at all. Contrary to classical decision theory, where there is always a single highest expected utility now one equilibrium might be Pareto-inferior with respect to another equilibrium. If the decision-makers are in such an inferior equilibrium position there is no way for individually rational players to induce a Pareto improvement. Only communication, mutual commitment and the like, probably supported by demonstration or simulation of the deadlock can help to overcome the impasse. There is no way for classical decision theory to model this type of problem *and problem support*. This advantage of game theory to distinguish between individual and group rationality can be termed ‘*logical sophistication*’.

Finally the interdependence of decision-makers in game theoretic formulations enables a more careful treatment of existing knowledge, memory of the involved parties. Experience and learning now not only consists in the updating of probabilities on the basis of observed data, as is the case in classical decision theory. Now knowledge is knowing models of others and eventually ascribing probabilities to these models too. Contrary to the classical view which mainly is pre-occupied by one-shot decisions game theory starts with fully developed entities using their heterogeneous knowledge structures to achieve far-sighted goals. Interestingly enough this feature of game theory becomes most evident in the theoretic development of equilibrium concepts: Myopic Nash-equilibrium (Nash, 1950) recently has been challenged by new far-sighted equilibrium concepts (e.g. Aaftink, 1989 and Brams, 1994) where starting positions are essential for long-run strategies - history matters. This property of game theory can be called ‘*knowledge heterogeneity*’.

So while classical decision theory might be appropriate for a wide range of problems, there definitely are specific advantages of the game-theoretic approach.

3. CSCW: DECISION THEORY OR GAME THEORY?

‘Computer Supported Cooperative Work’ (CSCW) deals with the possibilities of supporting the work of groups by technical systems.
Since in the meantime CSCW has become an established research field, many different attempts to define CSCW have been undertaken. While some authors (e.g. Allen (1990)) classify technical systems by terms of the underlying technical infrastructure, others (such as Holand and Danielson (1989), DeMichelis (1990)) approach the issue by trying to define the basic concept of CSCW, namely cooperation. DeSanctis and Gallupe (1987) introduce properties of CSCW, (namely overcoming time and space), while McGrath (1994) puts the focus on the meaning of the group’s task.

The latter focus is exactly the idea developed further by Egger and Hanappi (1994a), who define CSCW-systems as technical systems supporting a group’s *work*. Taking the meaning of work as starting point for analyzing functional requirements of CSCW systems leads to the conclusion that - in the words of Grudin (1994) “CSCW is nothing but a synonym for decision support systems". A closer look on working groups and their organizational environments leads to the view that CSCW-applications are systems supporting the assignment of group members to tasks and times).

In the following some more detailed aspects of this approach are presented:

Assuming that, as the notion Computer Supported Cooperative *Work* suggests, a group of several persons has to accomplish a common task, in this case the decision process is limited to the determination of task-time-person assignments (Schmidt, 1991).
Cooperation means that CSCW applications are used for tasks which cannot be performed by one single person: Either because the work process requires more people (e.g. in order to be finished within given times) or the work process requires different persons' qualifications. In any case a distribution of sub-tasks over the group members has to be worked out. Contrary to pure process-automation, where working people are treated as resources being assign to certain tasks, CSCW pre-supposes that group members are in a position to formulate personal preferences and at least partially can realize them. This is exactly what defines the *scope of negotiations.*

Assume that group members do have time and task preferences. This implies that they will try to push their interests - even if certain conditions (such as externally determined deadlines or contractually specified obligations) still are treated with highest priority. To qualify as a CSCW-system the labor process at least partially has to offer possibilities to take into account the preferences of the team members. As theoretical consideration (e.g. Fisher, 1981) as well as empirical studies (Egger, 1995) show, power and status play important roles in the decision process of groups. The influence of the interrelational level on operational decisions emerges due to formal or informal power distributions: The power of persons at higher hierarchical positions is expressed by higher autonomy allowing them to push their interests more successfully. Nevertheless also people at lower hierarchical level will try to find ways to bring in their preferences.

Since CSCW-systems shall support the planning procedure, the described phenomena cannot be neglected. The question therefore is, how to model these processes.
It is already evident that the two theories presented in the last section could be assessed according to their applicability for the mentioned cases. Since working groups are not considered to be homogenous in members, all having the same goals and interests, the decision making processes concerning the distribution of tasks and times among the group members is characterized by a rather competitive situation which already indicates that game theory is the more adequate tool for formalization.

Since a change of assignments for one group member generally induces consequences for other members, too - as long as the group is tightly coupled in the terminology of Perrow (1984) - the utility of a certain assignment of a person depends on the strategic choices of the others. Exactly this interdependence is the characteristic for a successful application of game theory which will be developed further in the following.

For negotiation modules in CSCW-applications the topic of bargaining is given, namely time-task-person assignments, and it is this fact which enables further specification: As one might observe in a checklist Strauss (1979) produced for negotiation situations a most important point is missing, namely the specification of the rules and mechanisms of the bargaining procedure itself. This is so, because Strauss rather aimed at the specification of the *context* than at the core procedure, in order to cover a wide range of different core procedures. Knowing that the core of CSCW-bargaining concerns task-time-person assignments, it is possible to say more about the according decision making process:

First consider the set of *tasks*. As tasks are tasks of working groups, and therefore have to follow a certain logic of the production process, it is straight forward to formalize group tasks as Petri nets (Lawler, 1982). For CSCW this means that the whole Petri net represents the 'shared task' of the group, while the order (the sequence) of the tasks describes the *logic*.
Second, note that each *person* has to be characterized by two sets of properties: its qualification profile and its time preferences. Finally, *time* also enters the picture in Petri nets as far as they exhibit the temporal sequence of tasks. Summarized, time-task-person can be seen as a triangle of relations determining the scope of negotiation.

As Egger and Hanappi (1994a) have worked out the space of negotiation is visible if time constraints are inserted in the Petri net: the distance between earliest possible starting time and latest possible end time as compared to sub-task duration must be large enough.

A major deficiency of simple Petri nets is that it is pretended that the assignment of persons to tasks is unproblematic. The assumption behind is that there exists an unchallenged authority guaranteeing that the Petri net is carried out in the way it is determined by this authority (a view strongly correlated to the classical Tayloristic management style). Contrary to this, CSCW demands and enables the augmentation of the Petri net by a more sophisticated specification of a person's needs and qualifications (Fox, 1990).

If spelled in detail, the *person-task relation* already implicit in simple Petri nets is an assignment of tasks to persons. More precisely, an assignment which takes into account the qualifications of the persons available. Seen from the point of view of the persons each person can be ascribed a list of tasks, which it is able to perform. If the persons involved have many qualifications, in the case of a redundancy of qualifications, a certain type of flexibility, namely *qualitative flexibility*, becomes possible. Qualitative flexibility is the possibility to change the set of person-task assignments, due to the less stringent qualification constraints of a set of multi-qualified persons.
In this case a first type of autonomy, the *autonomy to choose between different Petri nets* (if they exist), will be enhanced too. If for a certain type of labor process different types of logical sequences are available the choice between them will be less bounded the broader the qualification structure of persons.

Furthermore the Petri net indicates time ranges implying when certain tasks have to be performed, when, as a consequence, certain qualifications are needed. With time ranges wide enough, as mentioned above, bargaining over person-task assignments includes both aspects: qualification and time.
This leads to the second important set of relations: *person-time relations*. Time ranges coming from the Petri net and reflecting the qualification structure have to be matched with time preferences of the concerned persons. A second type of flexibility thus arises, *time flexibility*. Time flexibility is the potential to shift the exact start and end time of tasks to achieve a better fit with personal time preferences.

The type of autonomy related to time flexibility, *time autonomy*, signifies the potential of persons to have their time preferences considered. This idea leads straight to the concept of power (Egger and Hanappi, 1994b).
With many persons insisting on their time autonomy discrepancies cannot be avoided. This implies that *person-person* relationships have to be specified to show which types of conflict resolution are possible in this organizational setting. In other words, *power* relations, i.e. the capacity of a person to limit the autonomy of other persons, have to be made explicit. Coming back to the idea of bargaining one requirement for cooperative work has to be that power in the form of decision competence is not too unequally distributed, as it would be in 'command-structured' groups. This is where the claim of CSCW as an instrument for ‘more democracy at the working place’ comes from.

The relations necessary for specifying decision situations can also be found in classical decision theory (Kreps, 1990) which distinguishes between three levels of specification:

1. The individual actor must be specified. In our case the actors are the group members.

2. The behavior of the actors must be specified. Here the usual assumption is that actors maximize expected utility or expected profits. In our model we assume a somewhat modified type of utility maximization: actors maximize expected utility increases due to less working time and less labor intensity. This modification is appropriate because of the specific institutional framework in which CSCW applications are to be found.

3. The definition of the institutional framework. While economic analysis often uses equilibrium analysis to restrict its otherwise too general models, we would propose to use a disequilibrium simulation model for an already particularly specified framework. Specification thus is the price paid for generality with a given equilibrium condition.

The institutional framework consists of a task specification, a specification of the group members and a specification of the organizational setting for decision making - which all are discussed in more detail in Egger and Hanappi (1994b).

The decision process modeled concerns the matching and bargaining over different proposals put forward by group members. A proposal always is a list of assignments of persons and time preferences to tasks. It needs not be fully specified in the sense that some or even all tasks might be left blank for further specification. The possibility of playing 'wild cards' is an important ingredient for strategic behavior.

The organizational setting also includes the bargaining rules structuring the decision-making process. These rules are thought to be known and accepted by all group members. One could suggest the following rule set illustrated in figure 3:

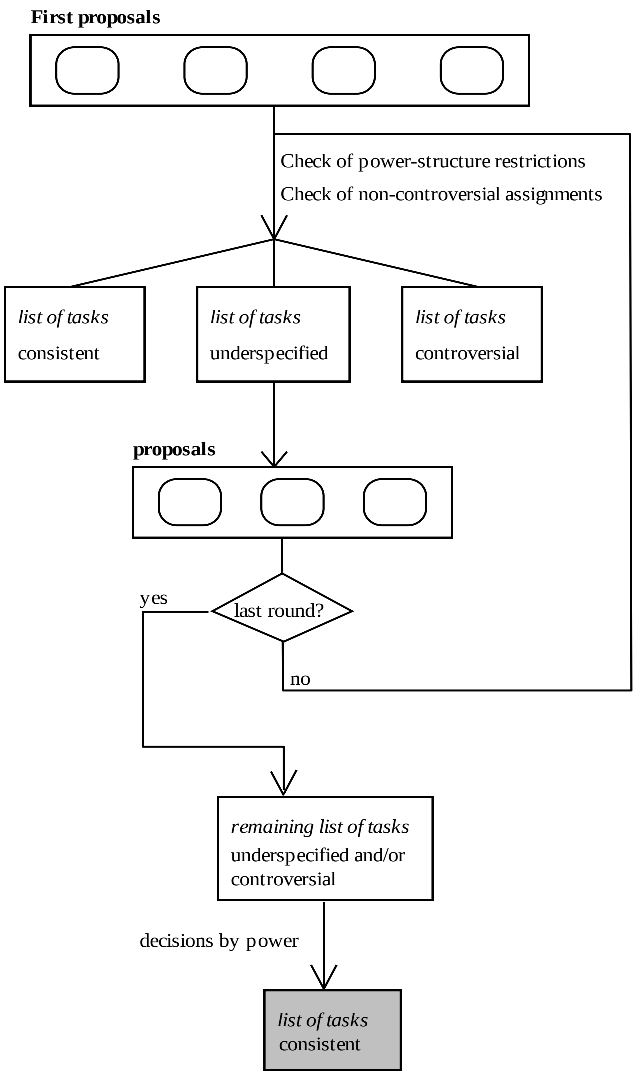

Figure 3: example for bargaining work distribution
(in: Egger and Hanappi (1994b))

In a first round the group members evaluate their proposals for persons-to-tasks assignments considering time constraints. After the presentation of the proposed schedules the most powerful person will probably dismiss propositions she/he finds not at all acceptable. The check of consistencies (which are commonly shared entries with or without 'wild cards') leads to a classification of the tasks: The list with consistent entries will be considered as accepted - but can also be used to check if originally controversial or underspecified tasks become consistent (e.g. due to time constraints). The list of controversial entries will be kept in evidence and the list of underspecified tasks will be exposed to further discussion.

The bargaining process will be terminated by a certain condition - typically after having played a limited number of times or if no controversial entry is left. If there still is a remaining list of underspecified or controversial entries the power relations of the group will determine the final solution by leaving the decision making competence to the most powerful person.

Until now the strategic behavior of the concerned group members has not been made explicit, but is hidden in what Giddens (1984) call ‘the backside region’. For most application fields this will be enough. Nevertheless game theory offers opportunities to simulate strategic behavior. In Egger and Hanappi (1994b) one example of implementing strategic behavior in terms of power-play was given. It can be imagined that for certain purposes, e.g. for scientific experiments with managerial decision simulations, the explicit models of strategies are illuminating interesting and important aspects.

This means that one has to distinguish between two types of applications of game theory in CSCW: If the group's dynamic is simulated (by implementing the strategic behavior of the group members) the system can be used for automated decision making (which is conflicting in other respect - compare also Egger and Hanappi, 1993) or as a mirror for learning processes (compare figure 4).

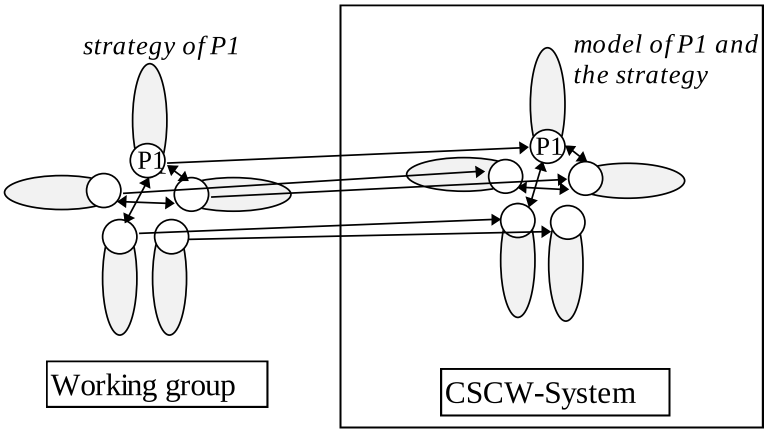

Figure 4: simulating group processes

By modeling the single group members and their strategies a simulation of the currently practiced planning procedure can be offered. This means that *the shared view on the group is modeled*. The group is asked to evaluate the results and to take them as a basis for negotiating new methods of planning or - if necessary - to vary the simulated model. The basic idea is to make the strategies - which are usually in the minds of the persons and therefore not overt - explicit to initiate learning processes.
Such an approach is also interesting for scientific research. Via experiments necessary knowledge on group dynamics can be discovered (which again could be implemented in the design of CSCW systems).

Real-time applications surely would imply another treatment of the strategic behavior of the group members. In order to realize highest possible utility under given circumstances for each of the group members, the according CSCW-system would have to offer technical support for them (compare figure 5).

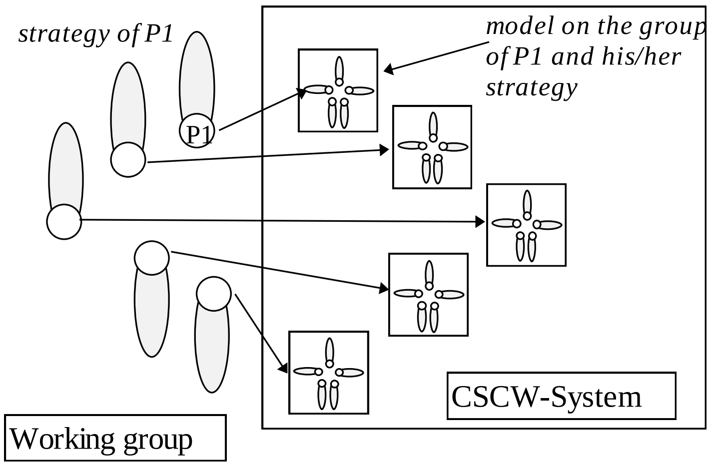

Figure 5: Simulating strategic behavior

The single group member is supported by a simulation model of the whole group (based on his/her own perception). Therefore a person can first “try out” a certain decision and - depending on the results of the simulation - choose the “best” one. Contrary to the former in this case *the views on the group of each team member are modeled*.

This module could serve as an interesting tool to support individual learning: By getting a feedback of the actual decision and its consequences the individual can adapt his/her model of the group dynamically.

Both types of game-theory applications (as illustrated in figure 4 and figure 5) offer challenging group simulations highlighting different aspects. Contrary to attempts to support the negotiation structuring (e.g. Kersten et al. (1988)) - which also offer very interesting results, the presented game-theoretic approach tries to simulate real decision situations - as given in working groups. Assessing CSCW in a realistic way - in terms of conflicting interests, strategic behavior of the group members, interrelational aspects of working groups and the like - leads us to the view that the presented game-theoretic formalization tools are more adequate than decision theory.

CONCLUSION:

Coming back to the main aspects of decision theory and game theory and confronting them with the purpose of CSCW-applications leads to the perspective that game theory offers more sophisticated forms of modeling group dynamic aspects:
In real world settings of working groups there are always very specific ways of realizing the various necessary tasks and roles (such as coordination, synchronization, controlling and the like). These aspects are strongly interwoven with the organizational circumstances determining the forms of negotiation or conflict handling of the team (compare also Egger, 1994). In other words there exist specified rules. Modeling these rules requires sophisticated formalization tools which game theory offers (in a preceding chapter this property was called *institutional richness*).
Since the view on working groups as consisting of homogenous elements seems to be somehow unrealistic and quite naive. This heterogeneity is mirrored by the heterogeneity of the types of knowledge these group members acquire and use. The preferred

perspective therefore is that there is a difference between the rationality of single individuals and group and sub-group rationality. Modeling this *logical sophistication* requires *knowledge heterogeneity* - and again leads to game theory.

Summing up, it can be stated that in fields where the power distribution of the concerned group members is not too unequally distributed and where it can be assumed that besides the group's commitments personal preferences and priorities exist and exert some influence too - briefly in fields like CSCW - game theory offers adequate models to simulate either group dynamic phenomena or real time planning practices.

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