Chapter 21

Liaising using a Multi-agent System

21.1. Introduction

The purpose of this chapter is to understand the technological spirit of tele-liaising system manufacturing, that is, an interactive computer that supports collective and discussed decision-making [MOR 05]. Such a system aims to facilitate collaboration among participants working remotely and asynchronously. The experiment presented here was developed under the ADNT project (decision and negotiation support for land management) co-financed by the Rhône-Alpes region. Initiated in 2001, it aimed to develop methods and tools for decision and negotiation support that would be useful to local development individuals involved in projects related to territory. This work was conducted in parallel under the ICA program (Incentive Concerted action) "City" (CNRS/Ministry of Research). Aimed at promoting fundamental and multidisciplinary research, the ICA "City" has opened up perspectives mixing ICT and city sciences and applying them to major urban issues today. In the first part of this article, we will discuss our approach (section 21.2). In the second part, we will set it in relation to game theory (section 21.3).

The principle of the system proposed here will be presented in section 21.4. It is based on the analytic hierarchy process and adapts it to a multi-participant context, allowing each of them to associate with a software entity, called an agent. Each agent assists a participant and represents him/her in automatic dialogues. We will

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describe the assistant multi-agent system in section 21.5. This provides an aid to consultation.

21.2. Motivations

In the real world, most decisions involve a wide range of individuals. Their success depends on their adherence to a consultation process. The resulting decision must thus convince them that everyone's point of view is fairly represented. This observation is the origin of a change of perspective in the development of democratic and technological procedures. The decisions must be collective and discussed [CAL 01].

In the area of governance, we can indeed distinguish two modes of forming a general consensus: representative democracy and dialogic democracy. Representative democracy is an aggregation process of individual preferences through which laymen and individuals delegate their power to elected representatives and experts. Dialogic democracy is a participatory process of composition of perspectives and interests through which civil society debates and deliberates. Hybrid forums, consensus conferences and discussion groups, whether they focus on sociotechnical controversies (BSE, gene therapy, mobile telephony, etc.) or territorial projects (motorway, nuclear power plant, water management, etc.), are dialogic democratic experiments.

Our work contributes to the last modality. It is about providing a computer support tool for liaising so that participants can collaborate remotely and asynchronously. We asked as prerequisite that the decisions previously taken in camera, whose justification remains obscure, could become open and transparent via the computer tool. This change of perspective allows us, from a social and political point of view, to take advantage of the expansion of the consultation circle in order to enhance expertise and avoid potential bottlenecks. From the point of view of rational decision-making, it supports the idea of exploiting the creativity of different individuals during the formulation of the problem.

Our system [GOR 96, GOR 01] is therefore an intelligent computer tool that mediates debates in the context of a dialogic democracy to facilitate the identification and resolution of conflicts rationally, efficiently and fairly [MCB 01].

21.3. Game theory

Game theory was introduced in 1940 by Morgenstem and von Neumann [MOR 40]. Based on an economic model of reasoning, game theory views collective decision-making as an aggregation process of preferences from a theoretical viewpoint. The rationality of an agent is then defined using a gain function to evaluate his/her satisfaction compared to the alternatives considered. This theory provides criteria by which to measure the quality of collective decision-making processes. We may in particular evaluate the performance of the result obtained at the end of such processes.

In order to propose a system of tele-consultation based on a multi-agent system, a first approach is to associate an agent who represents each participant in automatic negotiations. According to this hypothesis, the individual delegates part of the decision process. The agent signals to the participant that he/she is assisting in the alternative recommended at the end of the negotiations. This approach, thus allows respecting the cognitive schema and the value system of each actor. The vision and understanding of the same problem are subject to subjectivity. However, Arrow's theorem [ARR 63] indicates that it is not possible to build a satisfying social choice function when we have more than three alternatives. According to this theorem, if we consider a group of agents each equipped with its own preference relation and a set of more than three alternatives, there is no social choice function that satisfies the following properties:

universality, i.e. the social choice function must be defined whatever the preferences of the agents are;

non-dictatorship, i.e. no agent should be able to impose his/her preferences, regardless of the preferences of others;

unanimity, i.e. when all of the agents have the same preference, the social choice function must associate the same preferences with society;

indifference of irrelevant alternatives, i.e. the relative ranking of the two alternatives should depend solely on their relative position for the agents and not on the ranking of third-party alternatives.

Economists call preferences a complete pre-order or a complete order, that is a reflective, transitive and total relation. In the case of an order, we then speak of strict preferences: the relation is antisymmetric. The property according to which the social choice function should be indifferent to non-relevant alternatives implies in particular that if we consider only one subset of alternatives, the social choice function must not lead to another ranking of this subset. The result of the second round of Presidential elections held on April 21, 2002 is one example of it. The inability to guarantee the existence of a quality process of collective decision-making was mathematically demonstrated by Arrow [ARR 63]. It only confirms the necessity to go beyond game theory and offer to assist in the debate(act as a consultant to facilitate the search for an agreement but leave the final decision to the participants).

21.4. The principles

By supporting and not replacing human judgment, users are at the heart of the problem.

The system represented in Figure 21.1 is based on the negotiation support system proposed by Ito and Shintani of Japan [ITO 97]. It is based on a multi-agent system, where each software entity assists a user and interacts with the other agents in the system. We propose functions for the collaborative development of argumentative schemas on one hand, and to clarify consistencies and inconsistencies among the preferences of the participants in order to detect consensus and conflicts on the other.

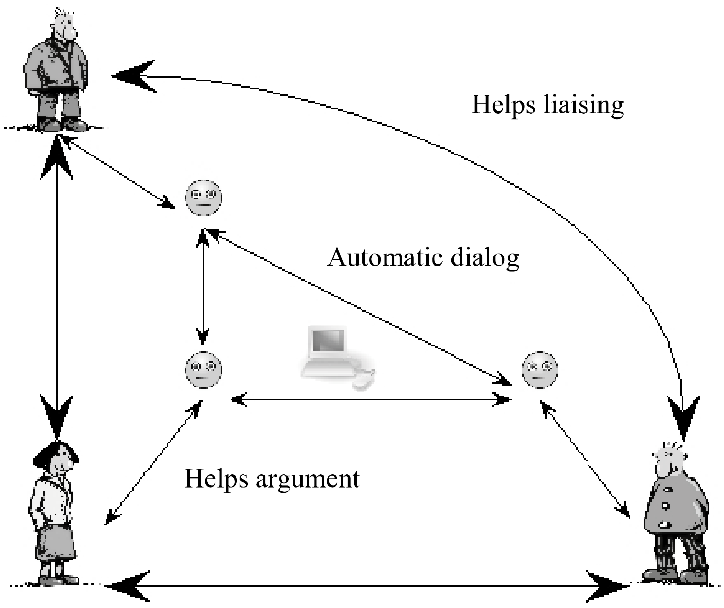

Figure 21.1. *Principle of the consultation support system*

In the field of territorial management, decision support tools used by participants are mostly based on multi-criteria analysis methods. These techniques are dedicated to clarify the understanding of a decision problem and its resolution. They become multi-criteria when the problem has several conflicting objectives.

We were particularly interested to the *Analytic Hierarchy Process* (AHP) proposed by Saaty [SAA 01]. It is a powerful and flexible decision process that facilitates the expression of preferences and allows decision-making using the judgments of the decision-maker, whether they are qualitative or quantitative.

This method is divided into three steps: the construction of a representation of the problem, the expression of preferences and the summary of judgments. Our goal will be to adapt this method to a multi-participant context.

To illustrate our point, we will now consider the problem of the location of International Thermonuclear Experimental Reactor (ITER), the first experimental installation of a thermal nuclear fusion plant.

21.4.1. *Representation of the problem*

Firs, the analytic hierarchy process (AHP) allows the development of an argumentative outline [GOR 97, RIT 73] to obtain a representation of the problem. In order togather precise knowledge, our mind structures the complex reality into various components, divides them in turn and so on, in a hierarchical way. In a complex situation, we build taxonomy of evaluation criteria to structure decision-making.

AHP builds the problem into a decision hierarchy consisting of elements called "activities". The aim of the problem is identified and divided into sub-problems called "evaluation criteria". These allow a comparison of alternatives as being possible solutions to the problem to be elucidated. The criteria are in turn divided into sub-criteria and so on until we obtain leaves of taxonomy of criteria related to each other by an inheritance relationship.

Figure 21.2 illustrates this representation of the problem through the example of the location of ITER. The goal is to select the right location among three alternatives (in France, Canada or Japan), three implantation sites that are evaluated according to criteria such as quality of its ground (c_4) organized in taxonomy. This goal is broken down into two criteria: the quality of the site noted c_1 and its accessibility noted c_2; c_1 and $c_2$broken down into sub-criteria c_3, c_4, c_5, c_6 and c_7.

It is from this representation of the problem that preferences are expressed.

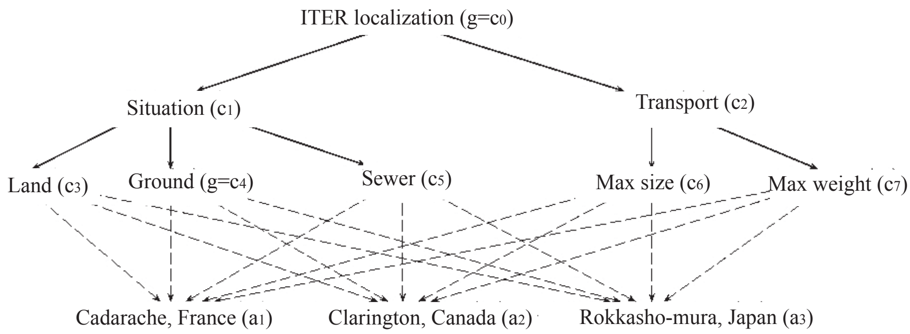

Figure 21.2. *Decision hierarchy for the location of ITER*

21.4.2. *Expression of preferences*

AHP is based on feelings and intuitive judgments.We describe the importance of an activity in relation to another:

– absolute (9);

– attested (7) ;

– determining (5) ;

– low (3) ; or

– equal (1).

We can estimate the relative weight of an activity *i* as opposed to an activity *j* given an evaluation criteria c_k in the field of definition corresponding to qualitative judgments of comparison (1, 3, 5, 7, 9) to their intermediate values (2, 4, 6, 8) but also to their reciprocal (1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/2). The set of distinctions among similar activities on the basis of the parent activity can be summarized in a matrix of pair-wise comparisons.

Let us consider the decision hierarchy of the previous example. Criterion c_1 that corresponds to the situation is divided into three sub-criteria:

– the quality of the land c_3 ;

– quality of the ground c_4 ; and

– the quality of sewers c_5.

Criterion c_4, the quality of the ground, is four times more important than criterion c_3, the quality of the land, and four times more important than criterion c_5, the quality of sewers. Thus, criteria related to the quality of the ground and sewers are considered of equal importance.

The matrix of pair-wise comparison on the quality of the land is represented in Table 21.1. The mathematical calculation of the Eigen vector (W) associated with the maximum Eigen value allows us to deduce the priorities of each of these criteria.

In summary, the method consists of comparing couples of similar activities of the same level on the basis of the parent activity and to establish distinctions between the two members of a couple by assessing the intensity of preferences of one compared to the other. Judgments thus expressed must be synthesized. Their consistency should also be checked.

A	**c_3**	**c_4**	**c_5**	**W**
c_3	1	1/4	1	1/6
c_4	4	1	4	2/3
c_5	1	1/4	1	1/6

Table 21.1. *Matrix of binary comparison*

21.4.3. *Summary of judgments*

Preferences are not necessarily consistent. The ratio of consistency allows us to evaluate this consistency. The more important the consistency ratio is, the less important preferences are. The threshold of acceptability is generally set at 10%. Within the limits of consistency thus defined, we can determine the relative priorities of the various activities.

A simple calculation allows us to determine the priority of an alternative compared to a criterion and deduce the optimal alternative as opposed to this criterion (the priority alternative). In the previous example, the respective weights of criteria c_3, c_4 and c_5 are 1/6, 2/3 and 1/6. Preferences are perfectly consistent: criterion c_4 is four times more important than criterion c_3 and four times more important than criterion c_5.

Preferences have been expressed using pair-wise comparisons among similar activities of the same level. The priorities of different activities as opposed to the parent activity are represented in Figure 21.3. It is from this information that the priority of alternatives is calculated. From this figure, we deduce by transitivity that the French site is optimal in relation to the goal.

In summary, this methodology of decision support allows a single individual to represent a problem, express his/her preferences from this representation and to synthesize its findings by measuring their consistency. Having defined the method used, in the next section we will present the elements of the underlying computer system that allows us to adapt this methodology to a multi-participant context through exchanges of information.

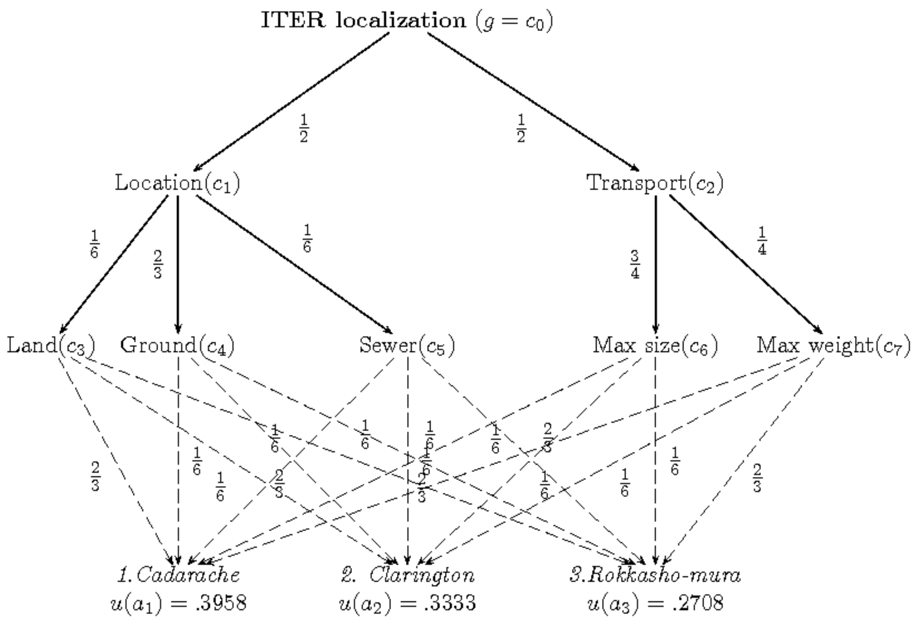

Figure 21.3. *Valued decision hierarchy for the location of ITER*

21.5. Multi-wizard system

The consultation support system proposed here is based on a multi-agent system, i.e. a set of software entities. Each agent assists a user and represents this individual in automatic dialogs. This allows participants to share their representation of the problem and compare their position. The participants may collaboratively develop their argumentative scheme and examine the consistencies and inconsistencies among their preferences.

21.5.1. Joint elaboration of an argumentative scheme

As with the HERMES [KAR 01] and ZENO [GOR 97] systems, our system allows jointly develops an argumentative scheme. Given that expertise is distributed, the process of sharing activities offers the possibility to create a common decision hierarchy while respecting the cognitive pattern of participants. When an agent has a new criterion in its decision hierarchy, it updates its preferences and spreads this activity throughout the system. The agent that receives such a proposal can confirm that it already has this criterion. Otherwise, it suggests this new criterion to its user. If the latter decides not to take this criterion into account, the agent declines this proposal. Otherwise, the agent carries out this proposal.

The process of sharing alternatives is very similar. A new alternative is suggested to the participants through the system. Users who integrate a new activity in their argumentative scheme must assess it. Similarly, participants can dissociate themselves from an activity. This consultation support system allows users to negotiate a common representation of the problem. All agents share the same goal but each has its own set of activities: alternatives and criteria. The set of activities can expand or shrink during the debate.

Let us consider three participants who wish to discuss the location of ITER. The joint decision hierarchy is represented in Figure 21.4. The common decision hierarchy initially consists of the goal and two Japanese and Canadian implantation sites. The first participant takes the common criterion c_0 and criteria c_2, c_6 and c_7 into account. He/she evaluates the two common alternatives: a_2 and a_3. The second participant considers the common goal g as well as two sub-criteria c_1 and c_2. He/she also takes into account two sub-criteria of c_2: c_6 and c_7. The third participant takes into account criteria c_0, c_1, c_3, c_4 and c_5. He/she evaluates three alternatives.

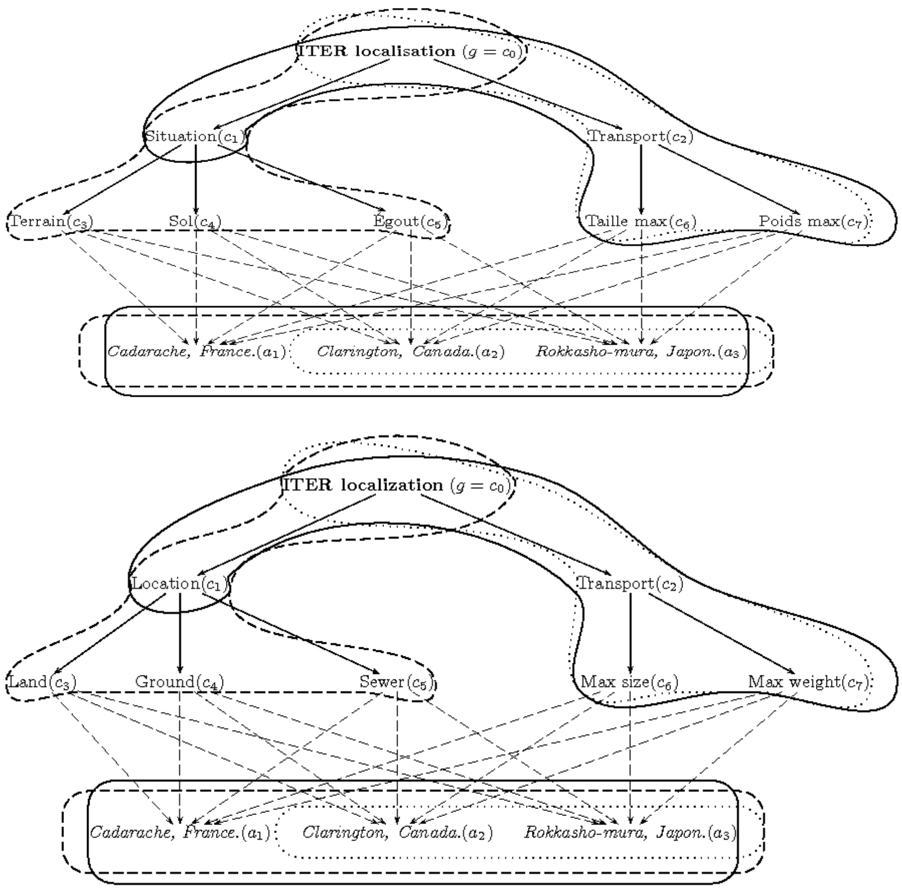

Figure 21.4. *Joint decision hierarchy for the location of ITER*

It is among activities shared by participants that conflicts and consensus are detected.

21.5.2. *Detection of conflicts and consensus*

Given that judgments are subjective, the system provides features that allow us to examine the consistencies and inconsistencies among the preferences of users.

Let us consider two assistant agents. A consensual criterion is a criterion that they share and for which one of the optimal alternatives is common. Inversely, a conflict criterion is a criterion that they share and for which the optimal alternatives are all different. A dialog between these two agents allows us to identify the major conflict or consensus that they share. A dialog ends when either one of the consensual criteria among the most general ones, or a conflict criterion among the most specific ones, is reached.

21.6. Conclusion

By adapting the AHP to a multi-participant context, the consultation support system proposed here can be based on a multi-agent system. Each agent assists a user and interacts with the other agents in the system.

On one hand, the system allows us to represent a problem, expressing preferences from this representation and synthesizing these findings by measuring their coherence.

On the other hand, the system provides features for the collaborative development of argumentative schemes and enables us to elucidate consistencies and inconsistencies among the preferences of participants and thus detect consensus and conflicts. To evaluate the uses of such a tool and its possible diversions, this proposal must be subject to empirical validation. The use of such a system furthermore not only requires the use of a computer by all participants in the project considered and the absence of specific knowledge prior to implementation, but also greater transparency of debates on the part of all of the decision makers.

21.7. Bibliography

[ARR 63] ARROW K.J., *Social Choice and Individual Values*, Wiley, New York, 1963.

[CAL 01] CALLON M., LASCOUMES P., BARTHE Y., *Agir dans un Monde Incertain*, Seuil, Paris, 2001.

[GOR 01] GORDON T., MARKER O., "Mediation systems" , in Lorenz M., Hilty and P.W. Gilgen, (eds.), *15th International Symposium Informatics for Environment Protection*, Metropolis Verlag, p. 737-742, 2001.

[GOR 96] GORDON T., "Computational dialectics", in Hoschka P. (ed.), *Computer as Assistants – A New Generation of Support Systems*, Editions Lawrence Erlbaum Associates, Mahwah, NJ, p.186-203, 1996.

[GOR 97] GORDON T., KARAPILIDIS N., "The Zeno argumentation framework", *Proceedings of the 6th International Conference on Artificial Intelligence and Law*, ACM Press, New York, p.10-18, 1997.

[ITO 97] ITO T., TORAMATSU S. "Persuasion among agents: An approach to implementing a group decision support system based on multi-agent negotiation", *Proceedings of the 5th International Joint Conference on Artificial Joint Conference on Artificial Intelligence*, Morgan Kauffmann, 1997.

[KAR 01] KARACAPILIDIS N., PAPADIAS D., "Computer supported argumentation and collaborative decision making", *Information Systems*, vol. 26, no.4, p. 259-277, 2001.

[MCB 01] MCBURNEY P., PARSONS S., "Intelligent systems to support deliberative democracy in environmental regulation", *Information and Communications Technology Law*, vol. 10, no. 1, p. 33-43, 2001.

[MOR 44] MORGENSTERN O., VON NEUMANN J., *The Theory of Game and Economic Behaviour*, Princeton University Press, Princeton, NJ, 1944.

[MOR 05] MORGE M., Système dialectique multi-agents pour l'aide à la concertation, PhD thesis, School of Mines, Saint-Etienne, 2005.

[RIT 73] RITTEL H., WEBBER M., "Dilemmas in a general theory of planning", *Policy Science*, vol. 4, p. 155-169, 1973

[SAA 01] SAATY T., *Decisions Making for Leaders; the Analytic Hierarchy Process for Decisions in a Complex World,* RWS Publications, Pittsbur, United States, 1982, reprint 2001.