Computer-supported collaborative argumentation

Maxime Morge [1]

Abstract.

In this paper, we propose a computer-supported collaborative argumentation for the public debate. For this purpose, we use the Analytic Hierarchy Process (AHP), that can be viewed as an argumentation-based decision-making process, to help stakeholders to build an argumentation schema and to express preferences about it. Considering this multi-criteria decision-making as an argumentation-based decision-making, we construct a dialogue system of agents with reasoning abilities to support the group decision. Each user is assisted by an agent representing him in automated dialogues. Therefore, the system provides tools for the collaborative development of the argumentation schemas on one hand and to check the consistency or the inconsistency among preferences between two users allowing the conflicts and the consensus seeking on the other hand.

1 Introduction

The optimization of a linear function, called objective function, with linear constraints is a difficult problem. The more linear constraints are, the more difficult the problem is. However, this problem is not complex. By opposition, ill-structured problems and uncertainties informational situations are complex. We are interested in this paper in complex decision-making where the expertises are distributed and judgments are conflicting.

A group decision support system [3, 2] is an interactive computer-based system that facilitates the collaboration of a set of decision makers, also called stakeholders. Such a system is used for distributed and asynchronous collaboration, allowing users not to be in the same place and work at the same time. By supporting and not replacing human judgment the system acts as an assistant and advisor but leaves the final enforcement of decisions to the users. The stakeholders need appropriate tools in order to stimulate their participation giving them an active role.

In this paper, we propose a computer-supported collaborative argumentation for the public debate. For this purpose, we use the Analytic Hierarchy Process (AHP), that can be viewed as an argumentation-based decision making process, to help people to build an argumentation schema and to express preferences about it. Considering this multi-criteria decision-making as an argumentation-based decision-making, we construct a dialogue system of agents with reasoning abilities to support the group decision. Each user is assisted by an agent representing him in automated dialogues. Therefore, the system provides tools for the collaborative development of the argumentation schemas and to check the consistency or the inconsistency among users preferences in one-to-one interactions allowing the conflicts and the consensus seeking.

[1] Ecole Nationale Superieure des Mines 158 cours Fauriel, F-42000 Saint Etienne (France)

Paper overview. The paper starts in section 2 by describing the AHP in three steps. We show in section 2.4 that this multi-criteria decision-making can be considered as an argumentation-based decision-making. Section 3 describes the architecture of our system. This latter is based upon a multi-agent system described in sections 4 and 5. The tools used to support the group decision are described in section 6.

2 Argumentation support system

In this section, we propose an argumentation support system. For this purpose, we use the Analytic Hierarchy Process (AHP) [7] that can be considered as an argumentation-based decision-making process to help a stakeholder to build his argumentation schema, and to express preferences about it. The user is assisted in the three steps of the decision-making: the definition of the argumentation schema, the expression of judgments about it and the synthesis of preferences.

2.1 First step: constructing the argument schema

The AHP makes it easy to develop an argumentation schema to obtain a good representation of a problem, called decision hierarchy.

Definition 1 *A **decision hierarchy** is 4-uple* $DH = \langle g, C, A, \triangleleft \rangle$ *such as:*

- g *is the goal;*
- C *is the set of criteria ;*
- A *is the set of alternatives, i.e. possible solutions.* $Act = \{g\} \cup C \cup A$ *is called the set of activities;*
- $\triangleleft$ *is a specificity relation over activities defined such as* $act_{k1} \triangleleft act_{k2}$ *iff: either* act_{k1} *is a sub-criterium of* act_{k2}*; or* act_{k1} *is an alternative and* act_{k2} *is a leaf criterium. The most specific criteria are called leaf criteria. The corresponding transitive closure is written* $\triangleleft^*$.

Figure 1 illustrates this representation of a problem through the example of the ITER location, the first fusion device to produce thermal energy at the level of an electricity-producing power station. The goal, that consists of selecting the ITER location, is addressed by the three proposals made for siting ITER, i.e the alternatives.

2.2 Second step: making judgments

The user weights the relative importance of all elements in the argumentation schema in order to express judgments about it.

The user has to make pairwise comparisons between similar activities on the same level with respect to the activity on the upper level to evaluate the relative importance of one element over another with respect to a property. The relative importance could be: equal (1),

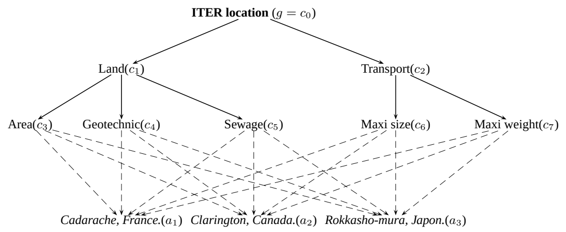

Figure 1. Decision hierarchy to select the ITER site

moderate (3), strong (5), very strong and demonstrated (7) or extreme (9). Sometimes one needs compromise judgments $(2, 4, 6, 8)$ or reciprocal values $(1/9, 1/8, 1/7, 1/6, 1/5, 1/4, 1/3, 1/2)$. For pairwise comparisons between n similar activities with respect to the criterium c_k on the upper level, a matrix $A_{c_k} = (a_{ij})_{i,j \leq n}$ is a preferred form. Each element evaluates the relative importance of one activity i over another similar activity j on the same level ($a_{ij} = \frac{w_i}{w_j}$).

Some proprieties of this pairwise comparison matrix: identity, reciprocity, default values reduce user's efforts to inform all pairwise comparisons. The goal of the next step is to synthesis the preferences.

2.3 Third step: synthesis of preferences

We provide with this decision-modelling two functions to calculate the optimal alternatives with respect to a criterium.

If n is the size of the pairwise comparison matrix $A_{c_k} = (a_{ij})_{i,j \leq n}$, and λ_{max} the max eigen-value, the associated eigenvector represents the priorities of the activities with respect to c_k ($W_{c_k} = (w_i)_{i \leq n}$). The priorities between activities can be calculated as follows:

Definition 2 *Let DH* $= \langle g, C, A, \triangleleft \rangle$ *be a decision hierarchy. A* ***valued decision hierarchy*** *is a triple VDH* $= \langle DH, I, J \rangle$ *such as:*

- *DH is the corresponding decision hierarchy;*
- $I(C \times C \to [0;1])$ *stands for the priority of a criterium with respect to the criterium on the upper level: if* $c_i \triangleleft c_j$ *then* $I(c_i, c_j) = w_i \in W_{c_j}$ *;*
- $J(A \times C \to [0;1])$ *stands for the priority of an alternative with respect to a leaf criterium:* $J(a_i, c_j) = w_i \in W_{c_j}$ *with* c_j *a leaf criterium.*

The extension of the function I (resp. J) corresponding to the transitive closure of the specificity relation ($\triangleleft^*$) is denoted I^* (resp. J^*). The priorities between alternatives make it possible to calculate an optimal alternative a_m of a criterium c_l ($a_m \subseteq \{a_n; \nexists a_o \in A \text{ s.a. } J^*(a_o, c_l) > J^*(a_n, c_l)\}$) and *a fortiori* an optimal alternative a_m of a valued decision hierarchy ($a_m \subseteq \{a_n; \nexists a_o \in A \text{ s.a. } J^*(a_o, g) > J^*(a_n, g)\}$).

This decision-modelling synthesizes the preferences by providing the following utility function: $\pi(a_i) = J(a_i, c_0)$.

However this Multi-Criteria Decision Making (MCDM) is a particular case of the economic rationality, it can also be considered as an example of argumentation-based reasoning.

2.4 MCDM: an example of argumentation-based reasoning

In this section, we aim at showing that this kind of argumentation schema and valuation is a particular argumentation system as proposed in [1]. In this way, the qualitative side of the decision-modelling improves the methodology when it is applied to a group.

Thanks to a decision hierarchy, the corresponding **decision language**, denoted $\mathcal{L}^{\text{DH}}$, contains a set of formulae corresponding to the activities (Act) and the logical connectives for the negation ($\neg$), the implication ($\rightarrow$) and, the xor ($\oplus$). The structure of a decision hierarchy could expressed in a knowledge base containing formulae of the corresponding decision language. The **decision base** (denoted Σ^{DH}) contains:

- g, *i.e.* the formula corresponding to the goal of the decision hierarchy;
- $\oplus_{\text{act}_l \triangleleft \text{act}_k} \text{act}_l$, *i.e.* the mutual exclusions between the similar activities;
- $\text{act}_k \rightarrow \text{act}_l$ (with $\text{act}_l \triangleleft^* act_k$), *i.e.* the implication rules between activities corresponding to the transitive closure of the specificity relation.

Because judgments are expressed with pairwise comparisons, we weight the likelihood of the corresponding formulae. Σ^{DH} is stratified into non-overlapping sets $\Sigma_n^{\text{DH}} \ll_{\text{VDH}} \dots \ll_{\text{VDH}} \Sigma_1^{\text{DH}}$ such that facts in Σ_i^{DH} are all equally preferred and are more preferred than those in Σ_j^{DH} with $i \leq j$. The **decisional preference relation** $\ll_{\text{VDH}}$ is defined such as:

- g is in Σ_1^{DH};
- $\oplus_{\text{act}_l \triangleleft \text{act}_k} \text{act}_l$ is in Σ_1^{DH};
- $(\text{act}_{k_1} \rightarrow \text{act}_{l_1}) \ll_{\text{VDH}} (\text{act}_{k_2} \rightarrow \text{act}_{l_2})$ is equivalent to $I/J^*(\text{act}_{l_1}, \text{act}_{k_1}) < I/J^*(\text{act}_{l_2}, \text{act}_{k_2})$.

According to this stratified decision base, we can construct a set of arguments as defined in [1]. An argument is composed of a conclusion and a set of formulas called support, from which the conclusion can be inferred. $\mathcal{A}(\Sigma^{\text{DH}})$ denotes the set of arguments built on Σ^{DH}. The arguments are linked together with two relations. Since the decision base is inconsistent, arguments may conflict. The relation written undercut captures these conflicts. The relation written pref decides between conflicting arguments. The set of acceptable arguments is written $\mathcal{S}_{\text{DH}}$.

Therefore, we can easily demonstrate that an optimal alternative wrt a criterium is supported by an acceptable argument.

3 System architecture

The system architecture (cf figure 2) is inspired by the group choice design support system which was proposed in [3]. It is based on a multi-agent system. Each agent assists a user and interacts each other.

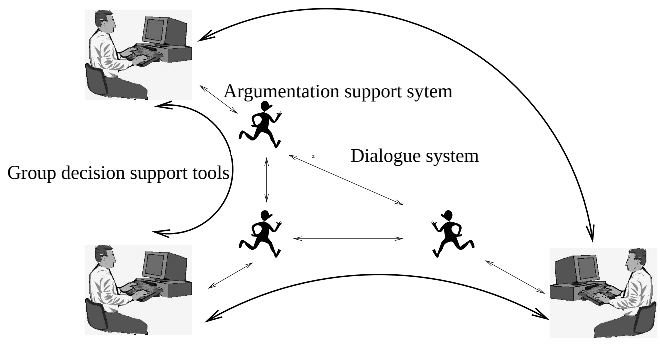

Figure 2. System architecture

As proposed in [3], an agent can negotiate according to the utility function given by the AHP. However, Arrow's impossibility theorem [4] shows that no social choice exists with more than three alternatives. This impossibility to satisfy desiderata conditions (possible aggregation of individual preferences, Pareto efficiency, independence of irrelevant alternatives, no-dictatorship) justify the need of group decision support tools.

For this purpose, we extend the first step to support the collaborative development of the argumentation schemas and the third step to check the consistencies and the inconsistencies among users preferences in one-to-one interaction. Before presenting such tools, we describe the dialogue system on these functionalities are based.

4 Dialogue system

Such a multi-agent system contains a set of dialogical agents. Each of them represents an user and manages the dialogues with the help of three components. An agent is in conformance with the following definition:

Definition 3 *A **dialogical agent** $ag_i \in AG_{\mho}$, is a tuple* $ag_i =< \Sigma^{DH_i}, \cup_{j\neq i} CSAct^i_j, \cup_{j\neq i} CS^i_j, \ll_{VDH_i} >$ *s.a.:*

- Σ^{DH_i} *is the decision base related to the valued decision hierarchy informed by the user;*
- $CSAct^i_j \subset Act_i$ *is the common store, i.e a set of activities in common with the agent* ag_j*;*
- CS^i_j *is the commitment store, observed by the agent* ag_i*, to which the agent* ag_j *commits during the dialogue;*
- $\ll_{VDH_i}$ *is the preordering relation on* Σ^{DH_i}.

Since each agent ag_i represent a user, the argumentation schemas (DH_i) and the argumentation valuations (VDH_i) may be different with the exception of the goal that is shared by all the users. This is the reason why each agent has its own decision base, Σ^{DH_i} and its own preordering, $\ll_{\mathrm{VDH}_i}$. The agent ag_i is associated with the following argumentation system: $\mathrm{AS}_i = \langle \Sigma^{\mathrm{DH}_i}, \text{ undercut }, \text{ pref }_{\mathrm{VDH}_i} \rangle$.

During dialogues, the agents exchange and share activities. The **common store**, written CSAct^i_j, is the subset of Act_i that the agent ag_j shares with the agent ag_i. Since the common stores are initially restricted to the goal, they will keep tracks of activities shared during the dialogues: criteria and alternatives.

During dialogue, agents take a stand for propositions. The **commitment store**, denoted CS^i_j, consists of the set of formulae perceived by the agent ag_i to which the agent ag_j commits. Since the commitment stores are initially empty, they will keep tracks of the observed agents'statements during a dialogue.

Dialogue agents utter moves each its turns. The syntax of moves is in conformance with a communication language $\mathcal{CL}_{\mho}$.

Definition 4 *A **move** $M_k \in \mathcal{CL}_{\mho}$ is defined by a 5-tuple,* $M_k = \langle S_k, H_k, R_k, DG_k, L_k \rangle$ *where:*

- $S_k =$ *speaker*(M_k) *is the agent that utters the move;*
- $H_k =$ *hearer*(M_k) *is the addressee;*
- $R_k =$ *reply*(M_k) *is the identifier of the move to which* M_k *responds* ($R_0 = \emptyset$)*;*
- $DG_k =$ *dialogue-game*(M_k) *is the dialogue game used to generate the answer;*
- $L_k =$ *locution*(M_k) *is the locution composed of a performative and a propositional content. The verb is one of them:* `assert`, `accept`, `challenge`, `withdraw`, `declare`, `acquire`, `decline`.

The meaning of the locutions will be specified by the three components used to manage the dialogues [5]:

1. an **argumentative component** specifies the rational conditions of a locution, and the corresponding argumentative tactics. The set of locutions is split in two parts: on one hand the locutions used to negotiate a common set of activities (`declare`, `acquire`, `decline`) and on the other hand locutions used to discuss about the optimal alternative with respect to this common argumentation schema (`assert`, `accept`, `challenge`, `withdraw`);
2. a **social component** defines the meaning of moves in a public perspective in order to be interpreted. The performative withdraw (not present in [6]) has no effect on the commitment stores but closes the dialogue;
3. a **conventional component** manages the sequence of moves. This component handles dialogical rules, regulating the dialogues whatever the dialogue game is, and sequence rules. These latters specify the answers allowed or not in a given situation by constraining the locution and the reply field.

A dialogue takes place between the speaker and the hearer of the first move M_0. A participant play one of the following **conventional roles**: either *initiator* (written init), *i.e.* the agent beginning the dialogue; or *partner* (written part) the agent is speaking to.

A dialogue game consists of the combination of these sequence rules. Because of concision, we will not detail the sequence rules used by this dialogue system but we present two dialogue games.

5 Dialogue game

In this section, we describe two dialogue games. The first one is used to modify the set of shared activities. The second one is used to elucidate the conflicts and consensus.

5.1 Dialogue game of activity submission

The goal of such dialogues is to reveal an activity taken into account by the initiator and suggest it to the partner.

The figure 3 shows two dialogue games of activity submission in the extensive form game representation where nodes are game situations and edges are associated with moves. For example, 1^{part} denotes a game situation where the exponent indicates the speaker of the next move.

A dialogue game is defined in a similar way to indicate to the partner that an activity is neglected.

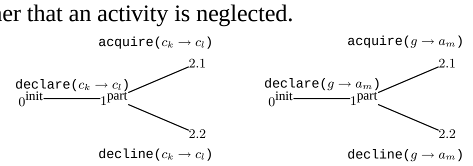

Figure 3. Dialogue game of activity submission

5.2 Dialogue game of persuasion

The goal of such dialogues is to reveal the position of the participants about the common goal.

The figure 4 shows an persuasion dialogue in an extensive form game representation.

In the following section, we show how such automated dialogues are useful to support the group decision.

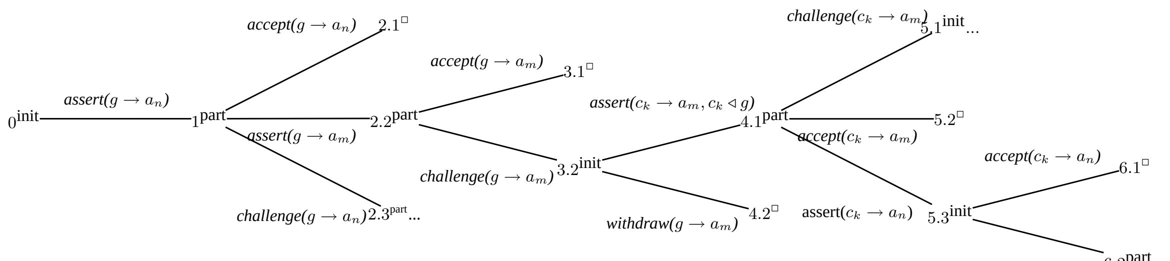

Figure 4. Dialogue game of persuasion

6 Group decision support tools

The dialogue system help the stakeholders to negotiate a joint representation of the problem and to check the consistencies or the inconsistencies between their preferences in face-to-face interactions. Therefore, we provide two functionalities to help the group in the first step and the third step of the methodology.

6.1 First step: collaborative development of the argumentation schemas

Because the expertises are distributed, the process proposed here to share activities, create a joint knowledge and, respect the reference systems of users. It helps the group to debate the problem.

When the agent ag_i has a new sub-criterium c_l of c_k in the decision hierarchy DH_i, it updates the valued decision hierarchy VDH_i and broadcast this modification in the dialogue system. Therefore, the agent ag_i begins a dialogue of activity submission with all the other agents having the criterium c_k in its decision hierarchy.

On the other side, the agent ag_j receiving a declaration of a proposition $p = c_k \rightarrow c_l$ can respond with an acquirement if the criterium c_l is in the decision hierarchy DH_j. Otherwise, it suggests the new criterium c_l to its user. Either this latter decides not to take this criterium into account and the agent ag_j declines the proposition. Otherwise, the agent ag_j acquires the proposition. In this latter case, the agent ag_j broadcasts this modification in the dialogue system.

The process to share alternatives is very similar. A new alternative is suggested to the other users. The latter ones who integrate this new alternative must valuate it as previously indicated (cf section 2.2). Moreover, the users can abjure activities. Finally, this group decision support system provides functionalities to negotiate a joint representation of the problem. All agents share the same goal but each of them has its own set of activities: alternatives or criteria. The sets of activities can expand or retract.

As stated in the following section, the common activities can be used to justify proposals.

6.2 Third step: conflict and consensus detection

Because judgments are subjectives, the system provides reasoning mechanisms to check for the consistencies or the inconsistencies among the users preferences in face-to-face interactions.

A criterium is consensual for two agent iff the optimal alternatives wrt it are the same. By opposition, a criterium is conflicting for two agents iff the optimal alternatives wrt it are different. We can easily demonstrate that a persuasion dialogue closes: either when one of the most general consensual criterium is reached; or when one of the most specific conflicting criterium is reached.

The figure 5 shows the valued decisional hierarchies of two agents: ag_1 (at left) and ag_2 (at right). A persuasion dialogue initiated by the agent ag_1 closes on the criterium c_4. A persuasion dialogue initiated by the agent ag_2 closes on c_3. Each of these criteria is one of the most specific conflicting criteria.

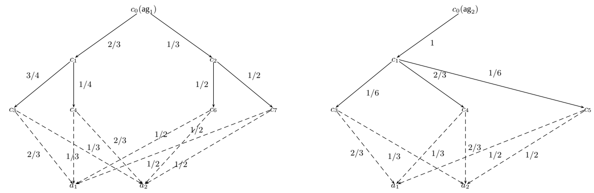

Figure 5. Decision hierarchies of the agents ag_1 and ag_2

Consequently, this dialogue game is useful for the analysis of the confrontation of preferences between two users.

7 Conclusions

In this paper we have proposed a computer-supported collaborative argumentation. For this purpose, we use the Analytic Hierarchy Process (AHP), that can be viewed as an argumentation-based decision-making process, to help people to build an argumentation schema and to express preferences about it. In this way, the qualitative side of the decision-modelling improves the methodology when it is applied to a group. Each user is assisted by an agent representing him in the automated dialogues. So, the system provides tools for the collaborative development of the argumentation schemas and to check the consistency or the inconsistency among users preferences allowing the conflicts and the consensus seeking.

An implementation and an empirical assessment must come to valid the adequacy and the significance of our approach.

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