A FORMAL APPROACH TO ARGUMENTATION IN GROUP DECISION SCENARIOS

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Abstract –Time and space consuming are disadvantages in group meetings but are easily faced in computer systems. Agent based group decision support systems reduce the loss usually associated to group work, turning more relevant the benefits that emerge from group meetings. Better decisions are taken after negotiation through choice and convincement. In this paper, a formal logic programming based system is proposed to represent agent knowledge and reasoning in order to be used in argumentation for decision group taking, supporting meetings where agents participate and communicate.

Keywords: Group Decision, Argument reasoning, Argumentation.

I. Introduction

The need of people to work in groups is well documented in literature: according to Simon [1] the escalating complexity of problems faced by organisations, due to lack of information and resources, is taking autonomy from individuals and substituting them with groups of human beings; Lauden & Lauden [2] say that 35 to 70 percent of managers time is spent in decision related meetings; Turban [3] states that the need of group work and meetings grow in the same proportion that grow the complexity of organisational decisions.

In everyday life we continually make decisions, individual or group decisions, even if we do not think of that. In our opinion group decision making processes are relevant for several areas, from the slightest problems, like choice a place to make vacations to health-care decisions, environmental decisions (e.g. water resources management), manufacturing decisions and others.

In group decision making process many times different types of conflicts and disagreements take place and it is necessary to overcome them. Argumentation can be an excellent choice to justify possible choices and to convince other elements of the group that one alternative is better or worst than another.

What we propose in this paper is a formal argumentation system to support group members in the elaboration and evaluation of arguments.

The work described in this paper is included in ArgEmotionAgents project (POSI / EIA / 56259 / 2004 - Argumentative Agents with Emotional Behaviour Modelling for Participants' Support in Group Decision-Making Meetings), which is a project supported by FCT (Science & Technology Foundation – Portugal) envisaging the use of Multi-Agent Systems approach for simulating Group Decision-Making processes, where Argumentation and Emotion components are specially important.

This paper has five main sections. The next section presents a short look on Group Decision Support. Section 3 presents a brief overview of argumentation, with special focus in logic based argumentation and their relations with GDSS. Section 4 presents a formal system to support the argumentation process in group decision scenario. Finally section 5 presents some conclusions and gives perspectives for futures developments.

II. Group Decision

The most evident benefit of group decision making is that it brings the experience and expertise of set of people to solve a problem, but there are others:

- Groups are better than individuals at understanding problems;
- People are more responsible for decisions in which they participate, which means less likelihood to resist to implementation;
- A group is better than an individual participant at detecting flaws in proposed ideas.
- A group has more knowledge than any one member individually;
- Synergy may develop so that the effectiveness of the group is greater than what could have been produced individually. Working in a group could stimulate the group members and consequently the process of decision making;

- Participants' differing knowledge and processing skills allow results that could not be achieved individually.

If there are big advantages associated to group work, there are also several dysfunctions related to this theme:

- Time consuming – group work is a slow process, only group member can speak at a time and there are a tendency to repeat what was already said;
- High costs - many hours of participation, travel time, travel expenses, and so on;
- Improper use of group dynamics - domination of time, or opinion by one or few members, and fear of speak by others;
- Tendency to rely on some members the most of the work;
- Tendency to make incomplete tasks analysis and to choose compromise solutions of poor quality.

A. Decision Making Structures

In order to understand better the characteristics of the decision making process, it is important to identify the different kind of decision support structures meetings. Holsapple and Whinston [4] propose the following classification (figure 1):

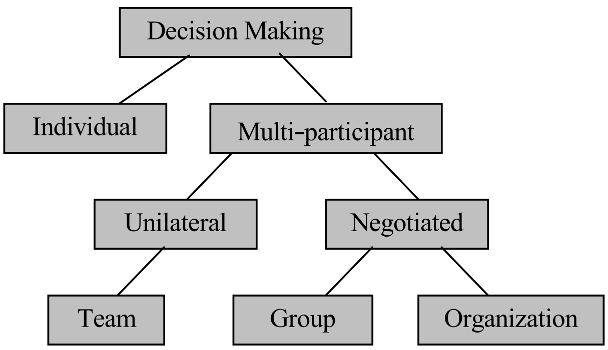

Figure 1- Decision making structure

Under this classification the decision-making can be individual or multi-participant. In the case that the decision is **multi-participant** (involves more than one person), there are yet two possible scenarios: the decision making could be **unilateral** or **negotiated**.

If the decision is Unilateral, that means that just one of the participants have the decision power, the remaining participants act like consulters. This structure is denominated of **team.**

If decision-making is negotiated, then two decisions making structures are possible: a group and an organization. The main difference between them relies in the authority distribution among the members of the decision meeting.

In **group** structure all the members have the same authority in the decision making process.

In an **organization** structure the members have different levels of authority, what could mean that for instance the number of votes of each member could be different.

In literature is possible to find several classifications of decision models and problem solving. One of the most used is Simon's classification that identifies the following phases: intelligence, design, choice and implementation [3] (figure 2).

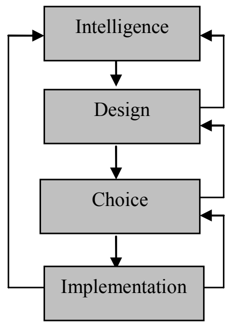

Figure 2- Simon's decision model

In the **intelligence** phase the focus is put on understanding and diagnosing the problem-solving environment. The **design** phase is composed by a set of activities that aim inventing, developing, and analyzing a set of possible decision alternatives for the problem identified in the intelligence phase. In the **choice** phase the goal is to select a particular decision alternative from those available. The **implementation** phase cover, as the name indicates, the implementation of the solution selected in the previous phase.

We have special interest in the choice phase, and in the use of argumentation to justify the choices made. If a positions defended by one of the group members is supported by arguments, is certainly more consensually accepted by the others.

B. Group Decision Support Systems

The term Group Decision Support System (GDSS) emerged effectively in the beginning of the eighty-decade. According to Huber [5] a GDSS consists of a set of software, hardware, languages components and procedures that support a group of people engaged in a decision related meeting. A more recent definition from Nunamaker and colleagues [6] says that GDSSs are interactive computer-based environment which support concerted and coordinated team effort towards completion of joint tasks.

Generically we may say that GDSS aims to reduce the loss associated to group work (e.g. time consuming, high costs, improper use of group dynamics, etc.) and to maintain or improve the gains (e.g. groups are better to understand problems and in flaw detection, participants' different knowledge and processing skills allow results that could not be achieved individually). The use of

GDSS allows groups to integrate the knowledge of all members into better decision making.

Group decision making involves discussion between group members, several GDSS includes mechanism to support the exchange of arguments to support points of views [7][8].

C. *Agent Based GDSS*

In literature there are already descriptions of agent based GDSS, some of them will be described afterwards.

Ito and Shintani [9] propose an architecture for an agent based GDSS where, it is associated an agent to each member (human) of the decision meeting. The key idea of this system is the persuasion mechanism between agents. The persuasion in this system is already done in pairs, for instance, agent A tries to convince agent B about the choice of alternative X, if agent A succeeds then they will form a group and together will start a new persuasion cycle and try to convince another agent about the choice of alternative X.

Kudenko and colleagues [10] propose a system named MIAU whose aim is to support a group of users in the decision of acquiring a good from an electronic catalogue. The catalogue items are characterized by a set of criteria (if the item of the catalogue is a car the criteria could be: price, technical characteristics, design or manufacturer, capacity of charge). MIAU intends to obtain a compromise solution that can be acceptable for all group members and for that it acquires the preference models of each user through interface agents. After this phase a mediator agent combines all the agents and tries to identify negotiable aspects and to suggest what seems to be a compromise solution. The users can accept or reject the proposed solution, and that may imply updates in the individual preference models. This process is repeated until a consensual solution is found.

Hermes [8] is a web-based GDSS that supports argumentative discourses between group members. The role of agents in this system is, for instance, to provide mechanisms to validate arguments consistency as well as to weight them. Agents in Hermes are also responsible for processes related with information search, for instance recovering information from previous discussions.

III. ARGUMENTATION

A classical definition of argumentation is from Toulmin [11] and defines argumentation as a process of making assertions or claims and providing support and justification for these claims using accumulated data, facts and evidence.

Traditional automated negotiation mechanisms do not improve the exchange of information (e.g. game theory, heuristics approaches) [12]. In the context of negotiation, argumentation is viewed as a mechanism to make possible the information exchange. Argument is viewed as a piece of information that may allow an agent to [13]:

- Justify its negotiation decision or option; and
- Influence others agents about the quality of its proposals.

The agent tries to turn its proposals more attractive, supplying additional information in the form of arguments [15].

But, in real negotiation situations, agents have not all the information and needs to reason. An agent must be able to construct its own arguments [12].

A. *Logic-based Argumentation*

The use of logic is welcome in the field of argumentation. Logic-based argumentation still presents a set of characteristics which can not be measured by a simplistic computational efficiency metric [14]:

- Adequacy to logic-based approaches to pre-argument reasoning: some agent development strategies define a stage that precedes the instant an agent starts to articulate an argument. This stage is called pre-argument reasoning and enables the agent to reason about such things as the right to participate in some decisions or the right to make part of a specific decision group. Due to the fundamental use of logic as a formalization tool and the manipulation of a logic Knowledge Base (KB), a set of rules is available in order to an argument be formulated;
- Similarity to the human reasoning processes: the use of logical mechanisms in reasoning enables easy construction of rules even by non-experts. On the other hand, the set of available rules (in an agent's KB) is largely human-readable;
- Reasoning with incomplete information: the use of null values, in combination with negation by failure, enables the use of incomplete information and a reasoning mechanism that deals with uncertainty. An agent is able to construct arguments where some information is neither true nor false;
- Argument composition and extension: the set of logical elements (rules) which compose an argument may be extended in order to strengthen the argument conclusion, therefore inumerous compositions may be available, which allows for an easy adaptation to any specific kind of argument and/or problem (e.g., information exchange). On the other hand, taking an argument for A and the insertion of a rule such as B←A, an argument for B is trivially reached by deduction.

B. *Knowledge Representation*

Knowledge representation techniques as a way to describe the real world, based on mechanical, logical or other means will be, always, a function of the systems ability to describe the existing world. Therefore, in the conception of a knowledge based system, it must be object of attention [17]:

- Existent Information: it may not be known in all its extension.
- Observed Information: it is perspectived by the experience, and obtained by contact or observation.

- Represented Information: with respect to a certain situation, it may be (ir)relevant to represent a given information. In spite of all the limitations, it is possible that observations made by different individuals, with distinct education and motivations, show the same set of fundamental data, function of its utility.

Prior to the characterization of the argument structure in terms of productions using logic programming extended by explicit or strong negation, the agent knowledge base has to be addressed. It will be built around a set of logical terms subject to proof, then allowing for action justification and argument construction.

Definition 1 - Agent Knowledge Base

The knowledge available in each agent's KB is made of logic clauses of the form $r_k{:}P_{i+j+1} \leftarrow P_1 \wedge P_2 \wedge \ldots \wedge P_{i-1} \wedge not\ P_i \wedge \ldots \wedge P_{i+j}$, where i, j, k $\in$ N_0, P_1, …,P_{i+j} are literals; i.e., formula of the form p or $\neg$ p, where p is an atom, $\neg$ stands for explicit negation and where r_k, not, P_{i+j+1}, and $P_1 \wedge P_2 \wedge \ldots \wedge P_{i-1} \wedge not\ P_i \wedge \ldots \wedge P_{i+j}$ stand, respectively, for the clause's identifier, the **negation-by-failure** operator, the rule's consequent, and the rule's antecedent. If i=j=0 the clause is called a **fact** and is represented as $r_k{:}P_1$.

An Extended Logic Programming (ELP) program (Π_{ELP}) is seen as a set of clauses, as given by Definition 1. Therefore, the agent KB is taken from an ordered theory OT=(T,<,(S, $\prec$)), where T,>, S and $\prec$ stand, respectively, for an agent's knowledge base in clausal form, a non-circular ordering relation over such clauses, a set of priority rules, and a non-circular ordering relation over such rules. An argument (i.e., a proof, or series of reasons in support or refutation of a proposition) or arguments have their genesis on mental states seen as a consequence of the proof processes that go on unceasingly at the agent's own knowledge about its states of awareness, consciousness or erudition. On the other hand, the mental states that have been referred to above are by themselves a product of reasoning processes over incomplete or unknown information; an argument may not only be evaluated in terms of *true* or *false*, but it may be quantified over the interval [0,1] (e.g., an agent may be able to deal a product with one of its peers using a set of conditions C_1; however it is not known if it can do the same thing with a set of conditions C_2, which may lead to further confrontation).

This work is supported by the developments in [17] where the representation of incomplete information and the reasoning based on partial assumptions is studied, using the representation of null values [16] to characterize abnormal or exceptional situations.

C. Argumentation and Group Decision

As it was mentioned before, the goal of GDSS is to help a group that is responsible for a decision making. In this process, many times, different types of conflicts and disagreements arise, and it is necessary to overcome them. Argumentation can be an excellent way to justify possible choices and to convince other elements of the group that one alternative is better or worst than another.

If a user of a GDSS could be helped by an agent that informs him/her what are the best arguments to convince another member of the group, this will be very useful.

In group decision context the word negotiation is viewed more like discussion of opinions and not like exchange of offers and counter-offers, which is its usual meaning in other areas (e.g. e-Commerce).

When a set of agents meets in a group decision meeting, interaction may take place, namely the exchange of opinions supported by the existence of different perspectives and point of views. The soundness of the process arises from the set of facts taken into consideration to produce opinions in favour or against a specific proposal; i.e., the facts taken from an ordered logic theory, lead to a logical conclusion, organizing themselves into an *argument*. The importance of an argument has much to do with the time at which it arises; i.e., an argument may be deemed as a *looser* or a *winner* when facing a counter-argument, taking into account its sequence of evaluation. The exchange of arguments and counter-arguments must stop when some conditions are satisfied. These conditions may or may not lead to the definition of a winning set of arguments, which is the case in systems where the main concern goes to take full advantage of the argument evaluation.

In a group decision meeting the achievement of a consensus it is more easily achieved if instead a just voting procedure, the individual positions are justified by arguments. The use of arguments between group members may contribute to exchange the member's perspectives about a specific subject.

IV. FORMAL SYSTEM

After a theory and a language have been established, in order to represent each agent's knowledge/information (from which it will draw the justification for each argument/counter-argument), a definition for argument must be reached. An argument is to be constructed progressively, being the antecedent of each rule composed by the consequents of previous rules. This definition is, perhaps, the most important one in the logical formalization of argument-based negotiation.

A. Global vs Local Knowledge

Each element that composes an argument may come from one of two main sources: global or local knowledge. Global knowledge is shared by the intervening entities and is, therefore, independent of a particular experience or local state. Local knowledge derives from sources that are not common to every agent, giving way to the possibility of contradictory conclusions upon confrontation.

Contrary to the definitions found in logical formalizations in Law, the Knowledge Base (KB) embedded in each agent may be quite different. The use of global or local knowledge conditions the capacity to determine the winner of a confrontation. As expected, local knowledge is not the best starting-point for a premise denial attack (e.g., a claim such as "my experience tells me that a car from the manufacture X is more secure than manufacture Y" is difficult to be stated as false by other agent group member, because he can not say what are the particular experiences of the other agent).

B. Negotiation Arguments

Definition 2 - Meta theorem-solver for incomplete information

A meta theorem-solver for incomplete information, represented by the signature demo:T,V→{true,false}, infers the valuation V of a theorem T in terms of false, true and unknown according to the following set of productions:

$$demo(T,true) \leftarrow T.$$
$$demo(T,false) \leftarrow \neg T.$$
$$demo(T,unknown) \leftarrow not\ T,\ not\ \neg T.$$

The concept of unknown/incomplete information is connected to that of null values. These elements are atoms that represent abstract concepts with no particular definition; i.e., elements which have a well-defined (or even non-defined) range of values have valid options.

Definition 3 - Negotiation argument with an implicit meta theorem-solver

Taking ordered theory OT, a negotiation argument is a finite, non-empty sequence of rules $\langle r_1,...,demo(r_i,V_i),...,r_n\rangle$ *such that, for each sequence rule* r_j *with P as a part of the antecedent, there is a sequence rule* r_i $(i<j)$ *on which the consequent is P.*

The use of such arguments, extended by a three-fold logic, is important due to their informative nature; i.e., one of the advantages of using argument-based negotiation lyes in the fact that information is conveyed in such a way that the other group members agents are able to evolve their counter-arguments in a parallel way (reaching a cooperative usage of knowledge)

The conclusion of an argument relates to the consequent of the last rule used in that same argument. Formally:

Definition 4 - Argument conclusion

The conclusion of an argument $A_1=\langle r_1,...,r_n\rangle$, $conc(A_1)$*, is the consequent of the last rule* (r_n).

Has it has been stated, the nature of the knowledge each agent has (local/global) is relevant for arguments and counter-arguments. By composing an argument with rules or facts that spawn from local knowledge (e.g., previous experiences), the attack or counter-argument launched by other agent's group members during the meeting is conditioned (due to the fact that local knowledge is hard to deny).

Taking into account the two forms of argument attack (*conclusion denial* and *premise denial*), a conflict amongst two agents (e.g., against/favour a specific proposal) can be formally specified:

Definition 5 - Conflict/Attack over arguments

Let $A_1=\langle r_{1,1},...,r_{1,n}\rangle$ *be the argument of agent 1 and* $A_2=\langle r_{2,1},...,r_{2,m}\rangle$ *be the argument of agent 2. Then,*

(1) if $r_{1,i} \in A_1$ *or* $r_{2,j} \in A_2$ *are local, the arguments are said to be in "probable conflict";*

(2) A_1 *attacks* A_2 *iff* A_1 *executes a conclusion denial attack or a premise denial attack over* A_2*;*

(3) A_1 *executes a conclusion denial attack over* A_2 *iff there is no local knowledge involved and* $conc(A_1)$ *is contrary to* $conc(A_2)$*;*

(4) A_1 *executes a premise denial attack over* A_2 *iff there is no local knowledge involved and* $conc(A_1)$ *is contrary to some* $r_{2,j} \in A_2$.

Having in mind the use of rational agents (i.e., those that do not undermine their own actions and are able to formulate coherent arguments), a proper definition of coherency must be formulated:

Definition 6 - Argument coherency

An argument $A_1=\langle r_1,...,r_n\rangle$ *is said to be "coherent" iff* $\neg\exists_{ai,aj}\ a_i,aj \in subarguments(A) \wedge i\neq j : a_i$ *attacks* a_j.

Taking into account the definition of conflict/attack and the concept of evolution of the decision it is possible to logically define the victory/defeat pair.

Definition 7 - Victory/Defeat of arguments

Let $A_1=\langle r_{1,1},...,r_{1,n}\rangle$ *be the argument of agent 1 and* $A_2=\langle r_{2,1},...,r_{2,m}\rangle$ *be the argument of agent 2 and* A_2 *is presented after* A_1*. Then,* A_1 *is defeated by* A_2 *(or* A_2 *is victorious over* A_1*) iff*

(1) A_2 *is coherent and* A_1 *is incoherent;*

(2) A_2 *is coherent, executes a conclusion denial attack over* A_1 *(coherent) and the conclusion rule of* A_2 *is prioritary (taking into account the OT theory) over* A_1*;*

(3) A_2 *is coherent, executes a premise denial attack over* A_1 *(coherent) and the conclusion rule of* A_2 *is prioritary (taking into account the OT theory) over* A_1.

Definition 8 - Priority clauses

Priority clauses, which are embedded in the KB of each agent, are rules of the form $PRIO{:}r_k{:}priority(K_i,K_j)$ *where* K_i *and* K_j *represent different knowledge classifications and* r_k *is the rule identification.*

Notice that priority rules are, by definition, set towards groups of clauses and not towards individual rules. This fact reduces computational complexity and expresses what is construed as the behavior of an human on similar circumstances.

C. Examples

Some examples may be presented to illustrate the previous definitions. Let agents A and B be engaged in a group decision process with the objective of buy a car in an environment with priority rules embedded in the KBs. Agents A and B share global knowledge and the set of priority rules of the different kind of block of knowledge's that compose the agent KBs.

During the meeting the agents must discuss the choice of a car based on the specific model and the colour and agree in a final decision. The rules that begin with *GK* are general knowledge, which is common to the group decision members. The rules that begin with *LK* are local knowledge.

Agent A::

% price for cars p1, p2 and p3
GK :price: r_1 *:price(p1,100).*
GK :price: r_2 *:price(p2,200).*
GK :price: r_3 *:price(p3,110).*

% car p1 and p3 are manufactured by x and p2 by y
GK : manufacturer:r_4 *: manuf(x,p1).*
GK : manufacturer:r_5 *: manuf(y,p2).*
GK : manufacturer:r_6 *: manuf(x,p3).*

% possible colours for the different cars
GK:general:r_7*:col(blank,p1).*
GK:general:r_8*:col(blue,p1).*
GK:general:r_9*:col(black,p2).*
GK:general:r_{10}*:col(blue,p2).*
GK:general:r_{11}*:col(red,p3).*
GK:general:r_{12}*:col(blue,p3).*

%agent define its interest in a car trough the colour, in this case any colour since the manufacturer is x
LK:general:r_{20}*:interest-col(Car):-*
_:_:_:col(_,Car),
_:_:_:manuf(x,Car).

% price overpowers manufacturer
GK : prio : r_{13} *: priority(price,manufacturer).*

Agent B::

% price for cars p1, p2 and p3
GK :price: r_1 *:price(p1,100).*
GK :price: r_2 *:price(p2,200).*
GK :price: r_3 *:price(p3,110).*

% car p1 and p3 are manufactured by x and p2 by y
GK : manufacturer:r_4 *: manuf(x,p1).*
GK : manufacturer:r_5 *: manuf(y,p2).*
GK : manufacturer:r_6 *: manuf(x,p3).*

% possible colours for the different cars
GK:general:r_7*:col(blank,p1).*
GK:general:r_8*:col(blue,p1).*
GK:general:r_9*:col(black,p2).*
GK:general:r_{10}*:col(blue,p2).*
GK:general:r_{11}*:col(red,p3).*
GK:general:r12:col(blue,p3).

%agent define its interest in a car trough the colour, in this case agent is only interested in blue cars
LK:general:r_{21}*:interest-col(Car):-*
_:_:_:col(blue,Car),
_:_:_:manuf(_,Car).

% price overpowers manufacturer
GK : prio : r_{13} *: priority(price,manufacturer).*

During the group decision about the car agent A vote that the choice must be car identified as *p3* using the argument $A_A = \langle r_6 \rangle$, however, agent B might argue and vote against with $A_B=\langle r_{13},r_1 \rangle$, representing a conclusion denial attack taking into account the priority rules shared by the community. Agent B is considered the winner due to the fact it uses a higher priority rule on the set of priority rules.

When agents are discussing the colour to the car *p3*, agent B propose and vote, obliviously in favour, of colour blue using the argument $A_B = \langle r_{12}, r_{21} \rangle$, agent A will argue and vote also in favour with $A_A = \langle r_{12},r_6, r_{20} \rangle$. The final choice of the group was car *p3* from manufacturer *x* with the *blue* colour.

Even if the group members agree with the same proposal, the exchange of arguments can be an excellent choice to reinforce the gains of selecting that proposal. Suppose the decision structure if of type team (defined in section II –A) the argumentation structure ca be very useful to explain the decision suggest by the decision team to its coordinator.

V. Conclusions

Logic clauses representing facts and rules are well-suited for such task, establishing a theory easily fed into an inference engine. The establishment of a clear definition of what is understood as an argument permits later considerations of conflict/attack strategies.

For computational reasons, and due to the necessity of establishing priorities on the set of clauses, the knowledge each agent has needs to form an non-circular ordered theory. The simplest priorities, which spawn from a particular ordering among the clauses, is not enough to express some of the possible scenarios. Priorities are usually set over knowledge bodies (e.g., local knowledge, previous meetings, general knowledge) and may be expressed as simple rules.

Through the present formalization, agents may be built in a logical fashion and arguing amongst agents has now a logical justification. The proximity to implementation languages (such as Prolog) is also an advantage.

There is already a first implementation of the formal system presented above. The prototype is being developed in JADE.

In the examples presented in section IV.C it was not considered the existence and respective treatment of incomplete information, however the defined formal system considers that fact, as can be seen in definitions 1 and 2.

Futures developments of this formal system will include factors like: credibility, reputation and the group member hierarchical position inside the organization. This last one will be very useful to analyze the importance (influence) of a specific participant in a group decision process.

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