# Consensus Decision-Making Using Argumentation (Doctoral Consortium)

Ayslan Trevizan Possebom
Federal University of Technology - Paraná
3165 September 7th Avenue.
Curitiba, Paraná - Brazil
possebom@gmail.com

## ABSTRACT

We propose an approach where a consensus decision-making may be reached using argumentation, building a common knowledge about the formulas of an argument depending on to what extent every formula is known by the group of agents. From the common knowledge and the set of formulas, we can compute the intrinsic and overall strength of the arguments and identify which of them are the most consensually accepted by the group related to a decision alternative.

## Keywords

Consensus Decision-Making, Argumentation, Acceptability

## 1. INTRODUCTION

While traditional group decision-making mechanisms use voting (majority, Condorcet, Borda, etc.) or the computation of a utility value to determine a winning alternative, the consensus decision-making is another paradigm that, instead the identification of the result which offers the best benefit, the conclusion represents the alternative that is preferred by most of the agents. Some principles of consensus decision-making are: agents (or most of them) should agree with the decision rather than majority vote; every agent can send their arguments justifying its points of view; there is no authority influencing the result; agents must cooperate with the group where individual's preference should be considered and incorporated when possible; every decision alternative should be discussed to determine pros and cons; the decision can be blocked when there is an action or property that cannot be satisfied, otherwise, the group of agents needs to consent with the group preference [5, 2].

We are exploring a mechanism to design consensus-decision making where a group of agents can dialogue through argumentation, identifying to what extent every formula in an argument is known or rejected by the group, leading to the intrinsic strength of the argument representing the acceptability of the argument for the group. From the intrinsic strength we can obtain the overall strength considering the received attacks. With the overall strength we can label every argument and apply an acceptability semantic and identify the most acceptable arguments that justify a decision alternative.

The approach should be applied in domains where the group preference needs to be detected and there are unknown or uncertain information in some agents. When a formula is common knowledge, agents can understand the reasons for the group to prefer any decision alternative or it can influence new opinions.

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## 2. DIALOGUE STAGE

The consensus process in short consists of three phases: opening, discussion and synthesis [4]. The dialogue stage proposed in this work manages the opening and discussion phases. In the opening phase the argumentation-based framework for consensus decision-making is established with the set of dialoging agents, the facilitator agent, the set of decision alternatives, the set of restrictive attributes that must be satisfied when a decision is made, and a waiting time so that agents need to wait before sending arguments.

To coordinate the speech movements, it is proposed the use of two software artifacts: *whiteboard* and *dialogue table*. Inspired in face meetings, the whiteboard consists of a list that contains the registered agents that have some argument to present. The agent in the first position on the list is able to make movements (send arguments to the group). The dialogue table consists of a set of tables, one table for every decision alternative, that store every argument sent by the agents. We consider a set of dialoging agents AG with every agent $ag_i \in AG = \langle \Sigma, \varepsilon \rangle$ with $\varepsilon$ being an expertise value and $\Sigma$ its knowledge base formed by formulas in propositional logic with $\Sigma = K \cup KO$ where K contains knowledge (facts and rules) the agent has about the environment and KO has knowledge acquired through dialogue, and a facilitator agent responsible for conducting the dialogue and filling the dialogue table artifact.

Consensus building requires the formation of a common knowledge [3]. We propose an approach to identify the set of agreement and rejection for every formula in an argument by means of a vote. When a formula is most agreed by the group, agents that do not have a position (lack of information) tends to accept that information and update their knowledge base.

*Example 1.* Let $CAF = \langle \{ag_1, ag_2\}, ag_f, \{a,b\}, \{y,z\}, 5 \rangle$ be a consensual argumentation framework. The dialoging agents are: $ag_1 = \langle \{(c,\ c \rightarrow b,\ d \rightarrow \neg b),\ (\emptyset)\},\ 0.5 \rangle$ and $ag_2 = \langle \{(\neg d,\ \neg d \rightarrow \neg b,\ c,\ \neg c \rightarrow b),\ (\emptyset)\},\ 0.5 \rangle$. The facilitator agent is $ag_f$. The decision alternatives are $\{b,a\}$. The restrictive attributes are $\{y,z\}$. The waiting time is 5 seconds.

The facilitator agent creates one dialogue table for every decision alternative. When an agent has any argument against the alternative or some argument that has already been sent by others, it registers in the whiteboard. We consider two types of attacks between arguments: undercut and rebuttal. When an agent is enabled to speak, it sends one argument in every waiting time. After the argument is approved by the facilitator, a new waiting time is required so that all agents can vote for the agreement or rejection in every formula. All formulas that are most accepted by the group is considered plausible and they are updated in the agent's KO base.

*Example 2.* Table 1 shows a dialogue about the decision alternative $b$. Agent $ag_2$ sent an argument and $ag_1$ rejected formula $\neg d \rightarrow \neg b$ because it has a similar formula that is not equivalent (d→¬b). Agent $ag_1$ sent an argument and $ag_2$ agreed with formula $c$ but rejected $c \rightarrow b$. Based on the Equation 1 with $\varepsilon_{ag_i}$ representing the expertise value for agent $ag_i$ and Agree[$\phi$] the set of agents that agree with formula $\phi$ or Reject[$\phi$] otherwise, agents can adopt formulas accepted by the group when fac($\phi$)>0. With fac(¬d)=0,5 in $\gamma$=1, $ag_1$ adopts this information and $\Sigma_{ag_1}$=⟨{(c, c→b, d→¬b), (¬d)},

**Table 1: Dialog for alternative *b***

| $\gamma$ | ag | arg | Agree | Reject | Att |
|---|---|---|---|---|---|
| 1 | $ag_2$ | ⟨{¬d, ¬d→ ¬b}, ¬b⟩ | ¬d[]<br>¬d→ ¬b[]<br>¬b[] | ¬d[]<br>¬d→ ¬b[$ag_1$]<br>¬b[$ag_1$] | |
| 2 | $ag_1$ | ⟨{c, c→b},b⟩ | c[$ag_2$]<br>c→b[]<br>b[] | c[]<br>c→b[$ag_2$]<br>b[$ag_2$] | 1 |

$$fac(\phi) = \frac{\varepsilon_{ag_i} + \sum\limits_{\varepsilon_{ag_j} \in Agree[\phi]} \varepsilon_{ag_j} - \sum\limits_{\varepsilon_{ag_j} \in Reject[\phi]} \varepsilon_{ag_j}}{1 + |Agree[\phi]| + |Reject[\phi]|} \quad (1)$$

## 3. DECISION-MAKING STAGE

This stage computes the strength of the arguments and applies a semantics to label the arguments and select the most consensually accepted by the group of agents. Initially the intrinsic strength is calculated considering the agreement and rejection in each formula of the argument. This value represents to what extent the argument is considered acceptable by the group based only on its formulas as demonstrated in Equations 4. To compute the intrinsic strength we need to investigate the influence of each formula in the argument. When fac($\phi$)>0 we have Equation 2 and for fac($\phi$)⩽0 we have Equation 3. Two functions were defined: *Split(arg)* that returns every formula in the argument, and *length(arg)* that returns the number of formulas in that argument. Following we need to compute the overall strength for every argument. This value represents the acceptability of the arguments considering all its counterarguments, expressed in Equation 5 adapted from [1]. The function *Att(arg)* returns all the attackers of the argument.

$$Infl[\phi] = \frac{\sum_{\forall ag_j \in (Ag - Reject[\phi])} \varepsilon_{ag_j} - \sum_{\forall ag_k \in Reject[\Phi]} \varepsilon_{ag_k}}{\sum_{i=1}^{i=n} \varepsilon_{ag_i}} \quad (2)$$

$$Infl[\phi] = \frac{\varepsilon_{ag_i} + \sum_{\forall ag_j \in Accept[\Phi]} \varepsilon_{ag_j} - \sum_{\forall ag_k \in Reject[\Phi]} \varepsilon_{ag_k}}{\sum_{i=1}^{i=n} \varepsilon_{ag_i}} \quad (3)$$

$$fi(arg) = \left( \frac{\sum_{\Phi \in Split(arg)} Infl[\Phi]}{length(arg)} + 1 \right) * 0.5 \quad (4)$$

$$fg(arg) = \frac{fi(arg)}{1 + \sum_{x_i \in Att(arg)} fg(x_i)} \quad (5)$$

When comparing two arguments, the one that holds the greatest overall strength is most consensually accepted and receives label *in*. When two linking arguments A and B (attacker and attacked) have the same overall strength, some standpoints can occur: (1) Argument A does not suffer attacks and should be considered *in*. This case may occur when there is insufficient information; (2) Argument B has a higher intrinsic strength and should be considered *in*. In this case, as argument B lost strength by the received attack and yet it has the same overall strength, it is more acceptable that argument A; (3) The overall strength of A and B are equivalents, so both should be considered *undec*, making it impossible to determine which of them will be considered more acceptable. We propose three acceptability semantics to cope with those standpoints where: when A and B are equivalent, both are considered *undec*; when A and B are equivalents, the one with the highest intrinsic strength is preferred and labeled *in*; and the set with conflict-free argument that has the highest sum of the overall strength.

The decision alternative can be blocked if one of the accepted arguments has at least one of the restrictive attributes. The order of preferences are given by: (1) the alternative with the highest number of accepted arguments, (2) the alternative that has the largest sum of overall strength, and (3) if we have a tie, then both can be equally considered.

## 4. CONCLUDING REMARKS

In this work we investigate the use of argumentation during dialogue among agents that search for consensus and work cooperatively. The main contributions are: a generic mechanism to identify the level of consensus about a formula in an argument and the building of a common knowledge; the proposal to calculate the intrinsic and the overall strength of the arguments based on the consensus evaluation; the use of acceptability semantics that can be applied to obtain the arguments that best justify a decision alternative. Future work includes the elaboration of properties of the system and experimentation.

## REFERENCES


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