Aggregation of Support-Relations of Bipolar Argumentation Frameworks*

Extended Abstract

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ABSTRACT

In many real-life situations, individuals may have different opinions on support-relations between arguments. When confronted with such situations, we may wish to aggregate individuals' argumentation views on support-relations into a collective view, which is acceptable to the group. In this paper, we assume that under bipolar argumentation theory, individuals are equipped with a set of arguments and a set of attacks between arguments, but with possibly different support-relations. Using the methodology in social choice theory, we analyze what semantic properties of bipolar argumentation frameworks can be preserved by desirable aggregation rules during aggregation of support-relations.

KEYWORDS

bipolar argumentation framework; social choice theory; support relation; graph aggregation

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1 INTRODUCTION

The attack relation has played a significant role in formal argumentation [1, 10, 13]. However, recent years have seen a revived interest in the support relation between arguments in argumentation systems [2–5]. In these systems, an argument can not only attack another argument, but it can also support another one. For example, an argument can support another argument by confirming its premise or undermine at least one of its attackers. The support relation between arguments is vital in modeling debates in real life.

Due to the incompleteness of information, or different positions, agents may have different opinions regarding the support relation between arguments. The bipolar argumentation framework [3–5] is a formalism of Dung's abstract argumentation framework which adds the capability of modeling the support relation between arguments, and will be considered in this paper.

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Agents many have different opinions on support-relations, which form argumentative stances. When a group of agents are engaged in a debate, we may wish to aggregate stances possessed by agents to obtain a collective decision agree on by the group. Given that there is a broad discussion of aggregation of argumentation systems with the attack relation [6–8, 11, 14], it is far from being clear what consensuses can be achieved when the support relation is involved in this process.

The goal of this paper is to investigate the aggregation of views of a group of agents in the context of bipolar argumentation. Given a set of arguments and a set of attack-relations between these arguments, agents might conflict with one another upon support-relations between arguments, and we may wish to aggregate such support-relations. Following the model introduced by Chen and Endriss [7] which originally developed by Endriss and Grandi [12], we consider the preservation of properties of bipolar argumentation frameworks, i.e., whether properties satisfied by individuals are preserved by aggregation rules.

We obtain both positive and negative results. For positive results, we show which semantic properties can be preserved by desirable aggregation rules. For negative results, we introduce two meta-properties for bipolar argumentation frameworks. These meta-properties have connections with the choice-theoretic axioms during aggregation. We then show that if a property P belongs to the family of the instances of the meta-properties, then any aggregation rule that satisfies certain basic axioms and that is supposed to preserve P must be a dictatorship. We then show that a semantic property of BAF satisfy these two meta-properties, which implies that the preservation of such property during aggregation of bipolar argumentation frameworks guarantees to impossibility results.

2 THE MODEL

An abstract bipolar argumentation framework (BAF) is an extension of Dung's abstract argumentation framework [10] in which a general support relation between arguments is added. Formally, a BAF is a triple $\langle Arg, \rightharpoonup, \rightsquigarrow \rangle$, where Arg is a set of arguments, $\rightharpoonup$ is a binary relation on Arg, which is called the attack relation, $\rightsquigarrow$ is a binary relation on Arg, which is called the support relation. Given two arguments $A, B \in Arg$, if $A \rightharpoonup B$ holds, then we say that A attacks B, if $A \rightsquigarrow B$, then we say that A supports B.

The attack relation and the support relation must verify the following constraint: $\rightharpoonup \cap \rightsquigarrow = \emptyset$, we call it *essential constraint.*

Definition 2.1. Given two arguemtns $A, B \in Arg$, a *supported attack* for B by A is a sequence $(A_1, \ldots, A_n)$ of arguments of Arg such that $A_1 \rightsquigarrow, \ldots, \rightsquigarrow A_{n-1}$, $A_{n-1} \rightharpoonup A_n$, $A = A_1$, $A_n = B$, and

$n \geqslant 2$. A *secondary attack* for B by A is a sequence $(A_1, \ldots, A_n)$ of arguments of *Arg* such that $A_1 \rightharpoonup A_2$, $A_2 \rightsquigarrow \ldots, \rightsquigarrow A_n$, $A = A_1$, $A_n = B$, and $n \geqslant 2$.

Definition 2.2. Let $\Delta \subseteq Arg$, let $A \in Arg$. Δ set-attacks A iff there exists a supported attack or a secondary attack for A from an element of Δ. Let $\Delta \subseteq Arg$ be a set of arguments, Δ is conflict-free iff $\nexists A, B \in \Delta$ such that $\{A\}$ set-attacks B.

Definition 2.3. Let $\Delta \subseteq Arg$ be a set of arguments, Δ is called *d-admissible* iff Δ is conflict-free and defends all its elements. Δ is a d-preferred extension if it is maximal (w.r.t. set-inclusion) among all d-admissible sets.

Fix a finite set *Arg* of arguments, a set $\rightharpoonup$ of attacks between arguments, and a set $N = \{1, \ldots, n\}$ of n agents. Each agent $i \in N$ supplies us with a set of supports $\rightsquigarrow_i$, which together with *Arg* and $\rightharpoonup$ gives rise to a bipolar argumentation framework $\langle Arg, \rightharpoonup, \rightsquigarrow_i \rangle$, reflecting her individual views on which supports between arguments are acceptable. A profile of support-relations $\boldsymbol{\rightsquigarrow} = (\rightsquigarrow_1, \ldots, \rightsquigarrow_n)$ is a set of support-relations provided by agents. An aggregation rule $F : (2^{Arg \times Arg})^n \rightarrow 2^{Arg \times Arg}$ is a function that maps a given profile of support-relations into a single support-relation. We denote $N^{\boldsymbol{\rightsquigarrow}}_{sup}$ by the set of agents who accept *sup* under profile $\boldsymbol{\rightsquigarrow}$, i.e., $N^{\boldsymbol{\rightsquigarrow}}_{sup} = \{i \in N \mid sup \in \rightsquigarrow_i\}$. Here we define desirable properties of aggregation rule.

Definition 2.4. Given an aggregation rule F, F is *unanimous* if $(\rightsquigarrow_1) \cap \ldots \cap (\rightsquigarrow_n) \subseteq F(\boldsymbol{\rightsquigarrow})$, F is *grounded* if $F(\boldsymbol{\rightsquigarrow}) \subseteq (\rightsquigarrow_1) \cup \ldots \cup (\rightsquigarrow_n)$, F is *neutral* if for any profile of support-relations $\boldsymbol{\rightsquigarrow}$, for any pair of supports sup_1, sup_2, $N^{sup_1}_{\boldsymbol{\rightsquigarrow}} = N^{sup_2}_{\boldsymbol{\rightsquigarrow}}$ then $sup_1 \in F(\boldsymbol{\rightsquigarrow})$ iff $sup_2 \in F(\boldsymbol{\rightsquigarrow})$, An aggregation rule F is *independent* if for any pair of profiles of support-relations $\boldsymbol{\rightsquigarrow}_1$, $\boldsymbol{\rightsquigarrow}_2$, for any support *sup*, $N^{sup}_{\boldsymbol{\rightsquigarrow}_1} = N^{sup}_{\boldsymbol{\rightsquigarrow}_2}$ then $sup \in F(\boldsymbol{\rightsquigarrow}_1)$ iff $sup \in F(\boldsymbol{\rightsquigarrow}_2)$.

Definition 2.5. An aggregation rule F is *dictatorial* if there is an agent i such that for any profile of support-relations $\boldsymbol{\rightsquigarrow}$, $F(\boldsymbol{\rightsquigarrow}) = \rightsquigarrow_i$.

Definition 2.6. The unanimous rule is an aggregation rule F with $F(\boldsymbol{\rightsquigarrow}) = \{sup \in Arg \mid sup \in (\rightsquigarrow_1) \cap \ldots \cap (\rightsquigarrow_n)\}$.

Definition 2.7. Let $i \in N$ be an agent, the dictatorship rule of individual i is the aggregation rule with $F_i = \rightsquigarrow_i$.

3 PROPERTIES OF BAFS

The problem we are considering is the preservation of semantic properties. Given a semantic BAF-property $P \subseteq 2^{Arg \times Arg}$ that is a set of supports on *Arg*, and P is satisfied by all agents, whether the output of the aggregation rule satisfies P.

Definition 3.1. An aggregation rule F preserves a BAF-property P if whenever for every profile $\boldsymbol{\rightsquigarrow}$ we have that $P(\rightsquigarrow_i)$ for all $i \in N$, then we have $P(F(\boldsymbol{\rightsquigarrow}))$.

The *essential constraint* is an example of a BAF-property that of particular interest. When we observe that all agents verify such semantic feature in a profile, we would like to see what aggregation rule preserves it under aggregation. We are also interested in the preservation of semantic extensions. Given a set of argument $\Delta \subseteq Arg$ that is a d-preferred extension of $\langle Arg, \rightharpoonup, \rightsquigarrow_i \rangle$ for all $i \in N$, we are interested under what circumstances Δ is a d-preferred extension of $F(\boldsymbol{\rightsquigarrow})$ as well.

Besides the properties identified above, we introduce two meta-properties, namely non-simplicity and disjunctiveness.

Definition 3.2. A BAF-property P is called **non-simple** if there exist a set $Sup \subseteq Arg \times Arg$ of supports and three individual supports $sup_1, sup_2, sup_3 \in Arg \times Arg \setminus Sup$ such that $\langle Arg, \rightharpoonup, Sup \cup S \rangle$ with $S \subseteq \{sup_1, sup_2, sup_3\}$ satisfies P if and only if $S \neq \{sup_1, sup_2, sup_3\}$.

Definition 3.3. A BAF-property P is called **disjunctive** if there exist a set $Sup \subseteq Arg \times Arg$ of supports and two individual supports $sup_1, sup_2 \in Arg \times Arg \setminus Sup$ such that $\langle Arg, \rightharpoonup, Sup \cup S \rangle$ with $S \subseteq \{sup_1, sup_2\}$ satisfies P if and only if $S \neq \emptyset$.

4 PRESERVATION RESULTS

For some BAF-properties, we obtained positive results during aggregation.

Proposition 4.1. *Every aggregation rule F that is grounded preserves the essential constraint.*

Let $sup \in \rightsquigarrow$ be a support, let $N = \{1, \ldots, n\}$ be a finite set of individuals (or agents, we assume that there are two or more agents), and let $\boldsymbol{\rightsquigarrow}$ be a profile of support-relations. Recall that $N^{\boldsymbol{\rightsquigarrow}}_{sup}$ is the set of agents who accept *sup* under profile $\boldsymbol{\rightsquigarrow}$. A *winning coalition* $\mathcal{W} \subseteq N$ is a set of agents who can decide whether to accept or reject a given support *sup*. Given an aggregation rule F, if F is neutral and independent, then F can be fully determined by a single set $\mathcal{W}$ of winning coalitions, i.e., for every profile $\boldsymbol{\rightsquigarrow}$ and every support *sup* it is the case that $sup \in F(\boldsymbol{\rightsquigarrow}) \Leftrightarrow N^{\boldsymbol{\rightsquigarrow}}_{sup} \in \mathcal{W}$. In our proofs, we will rely on the concept of *ultrafilters* familiar from model theory [9]. An *ultrafilter* is a collection is subsets of N satisfying *closure under intersection*, *maximality*, and $\emptyset \notin \mathcal{W}$. Here is a more formal definition.

Definition 4.2. An *ultrafilter* $\mathcal{W}$ on a set N is a collection is subsets of N satisfying the following conditions:

(1) $\emptyset \notin \mathcal{W}$
(2) for any pair of sets $C_1, C_2 \subseteq N, C_1, C_2 \in \mathcal{W}$ implies $C_1 \cap C_2 \in \mathcal{W}$ (closure under intersection)
(3) for any set C, one of C and $N \backslash C$ is in $\mathcal{W}$ (maximality)

We restate the simple result, which interprets a well-known fact of ultrafilter in our context.

> *Let F be an independent and neutral aggregation rule and let $\mathcal{W}$ be the corresponding set of winning coalitions for supports, i.e., $sup \in F(\boldsymbol{\rightsquigarrow}) \Leftrightarrow N^{\boldsymbol{\rightsquigarrow}}_{sup}$ for all $sup \in \rightsquigarrow$. Then F is dictatorial if and only if $\mathcal{W}$ is an ultrafilter.*

Lemma 4.3. *Let P be a BAF-property that is non-simple, and disjunctive. Then, for $|Arg| \geqslant 3$, any unanimous, grounded, neutral, and independent aggregation rule F that preserves P must be a dictatorship.*

If properties we are interested in are non-simple, and disjunctive, then we can apply Lemma 4.3 to achieve axiomatic results for them.

Theorem 4.4. *For $|Arg| \geqslant 5$, any unanimous, grounded, neutral, and independent aggregation rule F that preserves d-preferred extensions must be a dictatorship.*

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