Toward Consistent Agreement Approximation in Abstract Argumentation and Beyond

Extended Abstract

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ABSTRACT

In cooperative human decision-making, agreements are often not total; a partial degree of agreement is sufficient to commit to a decision and move on, as long as one is somewhat confident that the involved parties are likely to stand by their commitment in the future, given no drastic unexpected changes. In this work, we introduce models that allow autonomous agents to reach such agreements, using abstract argumentation as the underlying model.

KEYWORDS

Formal Argumentation, Dialogues, Agreement Technologies

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1 INTRODUCTION

In Artificial Intelligence (AI) research, devising formal models and algorithms that specify how autonomous agents can reach agreements is an important research direction [7]. In this context, the symbolic AI community considers *formal argumentation* approaches [1, 2] as particularly promising. From a more generic perspective, recent research has introduced a formal approach to determining *degrees of agreement* in formal argumentation dialogues, in which agents add arguments on a specific topic to a knowledge base [6]. The intuition behind this approach is that for practical purposes, it is often not necessary (or possible) to reach full agreement; instead, agents may decide that a certain degree of agreement on a given topic is sufficient to commit to roughly aligned decisions and move on. In this work, we put this intuition into the context of classical microeconomic (preference-based) decision scenarios, to then apply it to abstract argumentation.

2 CHOICE-BASED AGREEMENTS

Let us introduce an example to illustrate the contribution this paper summarizes. We have three agents (A_1, A_2, A_3), who are C-level managers and discuss which strategic initiatives among a, b, and c are the most important ones. Considering the big egos of the managers, reaching full consensus on all questions is an intractable problem. As long as everyone roughly agrees on the importance, the managers will be content, assuming that their objectives are aligned to a sufficient degree. Table 1 shows the *degrees of satisfaction* of the managers given the different choice options. For example, A_1 is most satisfied iff a, b, and c are all considered important strategic initiatives, and least satisfied iff no initiative is considered important. The rank index of an option is the agent's *degree of satisfaction* w.r.t. this option; *e.g.*, A_1's degree of satisfaction w.r.t. $\{a\}$ is 3. To determine the degree of satisfaction of an agent A_i with another agent's $A_j, i \neq j$, position, we determine the maximum degree of satisfaction of A_i w.r.t. the options that have the maximum degree of satisfaction for A_j (see: Table 2). To determine the degree of agreement between the whole group of agents, we introduce the following approaches:

- The **degree of minimal agreement** is the lowest degree of satisfaction of any agent, given an option that allows for a maximal lowest degree of satisfaction among all agents. In the example scenario, the degree of minimal agreement is 3, *e.g.*, provided by option $\{a, c\}$.
- The **degree of mean agreement** is the mean degree of satisfaction of any agent, given an option that allows for a maximal mean degree of satisfaction among all agents. In the example, the degree of mean agreement is 2, *e.g.*, the option $\{b, c\}$ provides the degrees of satisfaction 2 to A_1, 1 to A_2, and 3 to A_3, averaging at 2.
- Similarly, the **degree of median agreement** of the example is 2, *e.g.*, the median of $\langle 1, 2, 4 \rangle$, given the option $\{a, b, c\}$.

The degrees of agreement can then, for example, inform decisions on whether to further deliberate a given topic – in the example, the strategic initiatives – or guide future decisions of the involved participants; for example, the lack of management alignment as indicated by Tables 1 and 2 should cause each manager to be careful when making any future strategy-related decision.

Another aspect that can inform future decisions is how reliably the agents will keep their opinions given some constraints. This requires the analysis of the agents' decision processes, either by means of observation or – in particular in the case of artificial agents/computer systems – by formal analysis.

3 ARGUMENTATION-BASED AGREEMENTS

A straight-forward approach is to simply check whether the preferences of an agent are consistent over time, a property which,

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Table 1: Preferences of agents A_1, A_2, and A_3 as total preorders on $2^{\{a,b,c\}}$.

	$\mathbf{A}_1$	$\mathbf{A}_2$	$\mathbf{A}_3$
1	$\{a, b, c\}$	$\{b, c\}$	$\{\}$
2	$\{a, b\}$ or $\{a, c\}$ or $\{b, c\}$	$\{a, b, c\}$ or $\{b\}$ or $\{c\}$	$\{a\}$ or $\{b\}$ or $\{c\}$
3	$\{a\}$ or $\{b\}$ or $\{c\}$	$\{\}$ or $\{a, b\}$ or $\{a, c\}$	$\{a, b\}$ or $\{a, c\}$ or $\{b, c\}$
4	$\{\}$	$\{a\}$	$\{a, b, c\}$

Table 2: Matrix: degrees of satisfaction between agents in a choice-based agreement scenario.

	$\mathbf{A}_1$	$\mathbf{A}_2$	$\mathbf{A}_3$
$\mathbf{A}_1$	1	2	4
$\mathbf{A}_2$	2	1	3
$\mathbf{A}_3$	4	3	1

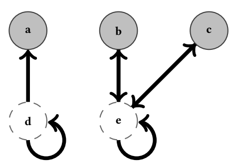

Figure 1: The scenario's argumentation framework.

for example, emerges from economic rationality[1]. To also account for the *knowledge* the agents use to establish their preferences, we apply abstract argumentation [4] to model the agents' inference processes. In the context of our agreement problem, we consider the choice items a subset of the *arguments* (atomic items) of an abstract argumentation framework. Based on an argumentation framework's arguments and their attack relation (binary relation on the set of arguments), an *argumentation semantics* determines which sets of arguments can be considered valid conclusions; these sets of arguments are called *extensions*. Given an argumentation-based model of an agreement scenario, we can impose formal constraints on argumentation semantics, that allow us to guarantee that – under specific conditions – the degree of agreement between a group of agents remains within specific bounds as new arguments are added to an argumentation framework. Let us extent the previous example to illustrate this. We assume that the agents have jointly constructed the argumentation framework as depicted in Figure 1, but they use different inference methods (argumentation semantics) to reach their conclusions. Indeed, if the agents were to use the following argumentation semantics, they would reach the conclusions as presented by the highest ranked options in Table 1. A_1: stage semantics [9]; A_2: preferred semantics [4]; A_3: grounded semantics [4]. To reflect the order indicated by Table 1, an agent can determine their preferences using a measure of similarity between any set of choice options (let us call them *topic arguments* in the context of abstract argumentation) and the most similar topic arguments returned by the agent's argumentation semantics. In any choice scenario, the agents can then make informed decision on how reliable an approximated agreement is, based on formal argumentation principles that are relaxed forms of monotony and ensure the following properties when *normally expanding* an argumentation framework (adding new arguments without changing the relationships between existing arguments, colloquially speaking):

(1) *Weak cautious monotony:* if no "new" argument attacks a specific extension of the original framework, every argument in this extension is also in an extension of the framework's normal expansion [5].
(2) *Causal reference independence:* if no "new" and *unattacked* argument directly or indirectly attacks a specific extension of the original framework, any argument in this extension is also in an extension of the framework's normal expansion.
(3) In addition, one can introduce an abstract class of principles, which we call *relaxed monotony principles*, that can roughly be described as "given an extension of the original argumentation framework, if some constraints hold true, then every argument in this extension is also in an extension of the framework's normal expansion".

Let us note that agents whose semantics do not support a specific relaxed monotony principle might still commit to enforcing it, roughly speaking by committing to violating the behavior of their semantics if necessary and as little as possible to satisfy the principle.

Let us note that while in the example, we focus on disagreements that are caused by differences between the argumentation semantics used by different agents, and we determine the degrees of satisfaction and agreement in the context of abstract argumentation based on similarity measures between sets of arguments, the underlying concepts can also be applied to approaches like *value-based argumentation* [3], that considers preferences over *values*, which in turn relate to the arguments in an argumentation framework. Given a value-based argumentation framework VAF, an agent's value preferences can be used to determine a *subjective* abstract argumentation framework AF with the same arguments, but only a subset of the attack relation; *i.e.*, in the context of value-based argumentation, our approach can manage disagreements "triggered" by subjective attack relations, and trace the impact of values on the different notions of degrees of agreements. An interesting future research direction is the integration of our work with emerging research on *extension-ranking semantics* [8] that establishes a preorder on the powerset of all arguments in an argumentation framework.

[1]Let us note that our agents are not necessarily economically rational, because given a set for choice options, the agents do not necessarily establish preference relations in which one option is strictly preferred over all others.

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