Merging argumentation systems with weighted argumentation systems: a preliminary study

C. Cayrol and M.-C. Lagasquie-Schiex

IRIT-UPS, Université de Toulouse
ccayrol@irit.fr, lagasq@irit.fr

Abstract. In this paper, we address the problem of merging argumentation systems in a multi-agent setting. Previous work [6] has proposed a two-step merging process in which conflicts about an interaction result in a new kind of interaction, called ignorance. However, this merging process is computationally expensive, and does not provide a single resulting argumentation system. We propose a novel approach to overcome these limitations by using a weighted argumentation system.

1 Introduction

Argumentation has become an influential approach in Artificial Intelligence to model cognitive tasks such as inconsistency handling and defeasible reasoning (e.g. [13, 18, 1, 19]), decision making (e.g. [9, 10, 12, 11]), or negotiation between agents (e.g. [17, 3, 2]). Argumentation is based on the evaluation of conflicting arguments. Most of the argumentation-based proposals are based on the abstract system proposed by Dung [7] (a set of arguments and a binary relation capturing the conflicts between arguments). Among them we are interested in a framework proposed for the *merging of argumentation systems*. Indeed in [6], a multi-agent setting has been considered in order to define argumentation systems for a group of agents from their individual argumentation systems. This amounts to make precise the set of arguments and the attack relation for the group. [6] has proposed a two-step merging process which first expands each agent's argumentation system for taking into account all the arguments (1), then computes a set of argumentation systems which are as close as possible to these expansions (2). For the first step, [6] has introduced a new kind of interaction between arguments, the *ignorance relation*, reflecting that an agent cannot conclude from the other agents that there is or not an attack between two arguments. However, [6]'s approach suffers from two important drawbacks: computing the output of the merging process is expensive and in the general case the merging process does not provide a single argumentation system, which complicates the definition of acceptability of (sets of) arguments for the group.

We propose a novel approach to the merging of argumentation systems which overcomes these limitations. Our idea is to refine the notion of ignorance and to replace it by a *weighted attack*. Recent works have proposed extensions of

Dung's argumentation system capable of handling varied-strength attacks ([14, 8, 4]). The idea is that attacks may have different strength and can be compared according to their relative strength. Our purpose is to take advantage of these works, in order to define a merging process such that the resulting system is a unique weighted argumentation system, easy to compute and to use.

In Section 2, we give the relevant background. Then, in Section 3, we propose a new approach for merging argumentation system into a weighted argumentation system (details and proofs are given in [5]). Section 4 concludes the paper.

2 Background

We first focus on Dung's theory of argumentation [7] in which only one interaction between arguments is taken into account.

Def 1 *An abstract* argumentation system $\mathbf{AS} = \langle \mathbf{A}, \mathbf{R} \rangle$ *over* $\mathbf{A}$ *is given by a finite set* $\mathbf{A}$ *of arguments and a binary relation* $\mathbf{R}$ *on* $\mathbf{A}$ *called an* attack relation. *Consider* a_i *and* $a_j \in \mathbf{A}$. $a_i\mathbf{R}a_j$ *means that* a_i *attacks* a_j

$\langle \mathbf{A}, \mathbf{R} \rangle$ defines a directed graph whose nodes are arguments and edges correspond to the attack relation. Whether a set of arguments can be accepted depends on the way arguments interact within the set but also w.r.t. the other arguments of $\mathbf{A}$. Collective acceptability is based on two key notions, conflict-freeness and collective defence, and leads to several semantics in [7].

Def 2 *Let* $\langle \mathbf{A}, \mathbf{R} \rangle$ *be an argumentation system. Let* $\mathbf{E} \subseteq \mathbf{A}$. *Let* $a \in \mathbf{A}$.

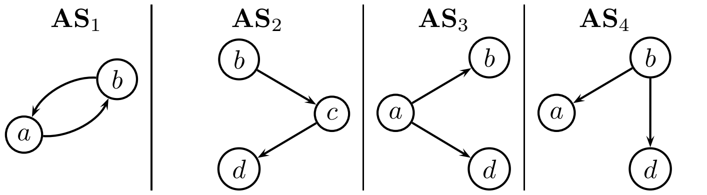
$\mathbf{E}$ *is* conflict-free *iff (if and only if)* $\nexists a, b \in \mathbf{E}$ *such that* $a\mathbf{R}b$. $\mathbf{E}$ (collectively) defends a *iff* $\forall b \in \mathbf{A}$, *if* $b\mathbf{R}a, \exists c \in \mathbf{E}$ *such that* $c\mathbf{R}b$. $\mathbf{E}$ *is* admissible *iff* $\mathbf{E}$ *is conflict-free and* $\forall a \in \mathbf{E}$, $\mathbf{E}$ *collectively defends* a. $\mathbf{E}$ *is a* preferred extension *iff* $\mathbf{E}$ *is maximal for set inclusion among the admissible sets.*

Then we consider a multi-agent setting where each agent has its own argumentation system. We cannot assume that one agent knows all the arguments which are known by the other agents. Moreover, the agents may disagree on the interactions between arguments. This problem already occurs in argumentation-based dialogue. The issue addressed in [6] concerns the combination of the different argumentation systems in order to achieve a collective decision about which arguments should be accepted. Given $\mathcal{P} = \langle \mathbf{AS}_1, \ldots, \mathbf{AS}_n \rangle$ a profile of n argumentation systems, two steps are needed:

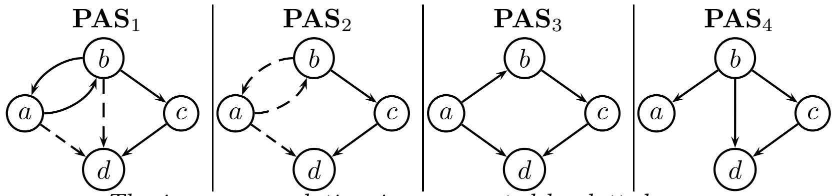
- ***expansion:*** Each $\mathbf{AS}_i = \langle \mathbf{A}_i, \mathbf{R}_i \rangle$ is expanded over $\mathcal{P}$ into $\mathbf{PAS}_i$ (partial argumentation system) for taking into account the knowledge coming from the other agents. $\mathbf{PAS}_i$ is built over $\mathbf{A} = \cup_i \mathbf{A}_i$ and contains two kinds of interaction: attack and ignorance.
- ***fusion:*** The $\mathbf{AS}'_j$ over $\mathbf{A}$ that are selected as the result of the merging process are the ones that best represent $\mathcal{P}' = \langle \mathbf{PAS}_1, \ldots, \mathbf{PAS}_n \rangle$ (*i.e.*, that are the "closest" to $\mathcal{P}'$ w.r.t. a given distance).

This proposal can be illustrated by the following example:

Ex 1 *Consider the profile* $\mathcal{P} = \langle \mathbf{AS}_1, \mathbf{AS}_2, \mathbf{AS}_3, \mathbf{AS}_4 \rangle$*:*

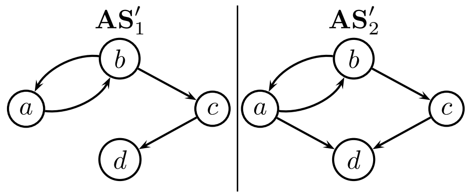


For each i, the expansion $\mathbf{PAS}_i$ *of* $\mathbf{AS}_i$ *over* $\mathcal{P}$ *is given by:*



The ignorance relation is represented by dotted arrows.

Then, using a usual distance (the edit distance) and the sum aggregation function, the merging process proposed in [6] produces the two following ASs:



Nevertheless, this proposal is computationally expensive and may produce several argumentation systems. Moreover, it does not enable to take into account the number of agents who agree with an attack when computing the expansion. Our proposal enables to graduate the interaction between two arguments by means of a weighted attack relation.

[8] has proposed weighted argument systems, in which attacks are associated with a numeric weight, indicating how reluctant one would be to disregard the attack. Here, we are interested in varied-strength attacks considering that the relative strength of the attacks enables to disregard some of the defences as in [14, 16, 15, 4].

Def 3 ([8] Weighted argumentation system) *A* weighted argumentation system *over* $\mathbf{A}$ *is a triple* $\langle \mathbf{A}, \mathbf{R}, w\rangle$, *denoted by* $\mathbf{WAS}$, *where* $\mathbf{A}$ *is a finite set of arguments,* $\mathbf{R}$ *is an attack relation on* $\mathbf{A}$ *and* w *is a function* $\mathbf{R} \rightarrow \mathbb{R}$ *assigning real valued weights to attacks.*

A weighted argumentation system can be considered as a particular case of the argumentation system with varied-strength attacks of [15, 4], using the natural ordering $\geq$ on $\mathbb{R}$. Then, considering that greater is the weight $w(a, b)$, stronger is the attack from a to b, the notions of vs-defence and vs-admissibility proposed in [4] become:

Def 4 *Let* $\mathbf{WAS} = \langle \mathbf{A}, \mathbf{R}, w\rangle$. *Let* a, b, $c \in \mathbf{A}$ *such that* $c\mathbf{R}b$ *and* $b\mathbf{R}a$. c vs-defends *a against b (or c is a* vs-defender *of a against b) iff* $w(c, b) \geq w(b, a)$ *(i.e. the attack from b to a is not strictly stronger than the one from c to b).*

Let $\mathbf{E} \subseteq \mathbf{A}$. $\mathbf{E}$ *is* conflict-free *in* $\mathbf{WAS}$ *iff* $\nexists a, b \in \mathbf{E}$ *such that* $b\mathbf{R}a$. $\mathbf{E}$ vs-defends *a iff* $\forall b \in \mathbf{A}$, *if* $b\mathbf{R}a$ *then* $\exists c \in \mathbf{E}$ *such that c vs-defends a against b.* $\mathbf{E}$ *is* vs-admissible *iff* $\mathbf{E}$ *is conflict-free and* $\forall a \in \mathbf{E}$, $\mathbf{E}$ vs-defends a.

3 Merging of argumentation systems into a WAS

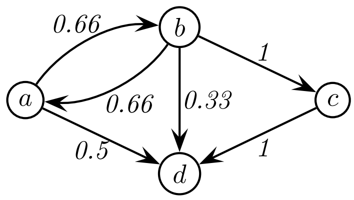
We propose to merge a profile $\mathcal{P} = \langle \mathbf{AS}_1, \dots, \mathbf{AS}_n \rangle$ (with $\mathbf{AS}_i = \langle \mathbf{A}_i, \mathbf{R}_i \rangle$) into a WAS such that the weight on an attack in the WAS represents the strength of the opinions of the group of agents concerning this attack. We use a global strategy considering each agent as a voting person and adding the votes for and against each interaction.

Def 5 (Merging of n ASs) *The merging of $\mathcal{P}$ is the WAS defined by* $\mathbf{WAS} = \langle \mathbf{A}, \mathbf{R}, w \rangle$ *with:* $\mathbf{A} = \bigcup_{i=1}^{n} \mathbf{A}_i$, $\mathbf{R} = \bigcup_{i=1}^{n} \mathbf{R}_i$ *and* $w : \mathbf{R} \rightarrow]0, +1]$ *defined by* $\forall (a, b) \in \mathbf{R}$, $w(a, b) = \frac{\Sigma_{i=1}^{n} w_i(a,b)}{n(a,b)}$ *with*

- $w_i(a, b) = 1$ *if* $(a, b) \in \mathbf{R}_i$, $w_i(a, b) = 0$ *if* $(a, b) \notin \mathbf{R}_i$
- *and* $n(a, b)$ *is the number of* $\mathbf{AS}_i$ *such that* $a \in \mathbf{A}_i$ *and* $b \in \mathbf{A}_i$.

Note that the merging of a profile of ASs results in a unique WAS. And this process can be done in linear time which is not the case of the merging process proposed in [6]. As for Dung's system, a WAS can be represented by a directed graph (nodes are arguments and weighted edges represent attacks). A missing edge has two possible interpretations: either all the agents who know both arguments agree on the non-attack, or none agent knows both arguments.

Ex 1 (cont'd) *Merging the profile of ASs given in Ex. 1 produces the following WAS:*



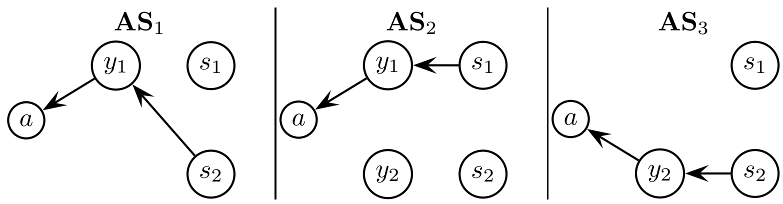
Using the notion of vs-defence, it follows that a *does not vs-defend* c. *This conclusion is not really surprising because among the three agents who know* a *and* b *only two agree on the attack from* a *to* b. *Then, we obtain two maximal (for* $\subseteq$*) vs-admissible sets* $\{a\}$ *and* $\{b\}$.

Note that, in the case when there is no conflict between the agents, the WAS corresponding to the merging of the ASs is an AS (all the weights are equal to 1). A similar result has been given in [6].

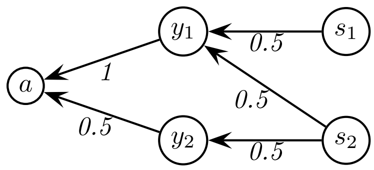
Some interesting properties enable to compare the pieces of information contained in **WAS** and in the initial $\mathbf{AS}_i$. Firstly, the arguments that are unattacked in each $\mathbf{A}_i$ remain unattacked in the resulting **WAS**. Secondly, the resulting **WAS** reflects the unanimity between the agents about attacks: if all the agents agree about an attack, this attack is in **WAS** with a weight equal to 1 (a simular result exists for the non-attacks). Consequently, situations when agents disagree can also be characterized, by the existence in **WAS** of an attack whose weight is not equal to 1. Moreover, the pieces of information contained in **WAS** can be also compared with the result of the merging process as defined in [6]: an attack weighted by 1 in **WAS** corresponds to an attack in each $\mathbf{PAS}_i$ and each resulting $\mathbf{AS}'_i$ (the converses do not hold). A similar result exists for the non-attacks.

The behaviour in case of unanimity shows that the merging preserves the information on which the agents do not disagree. This result is not surprising since the characteristic feature of our approach is that the merging occurs at the interaction level. However, we have no such result at the output of the argumentation systems; it may happen that an argument a is accepted[1] by all the agents who know it but a is not accepted in the WAS:

Ex 2 *Consider three agents with their respective ASs:*



The set $\{a, s_1, s_2\}$ is admissible in each $\mathbf{AS}_i$. The merging gives the following WAS:



After the merging, no vs-defence exists for a against y_1. So a cannot belong to a vs-admissible set. This result is not surprising: the attack from y_1 to a is known in $\mathbf{AS}_1$ and $\mathbf{AS}_2$ in which s_1 and s_2 are also known; but $\mathbf{AS}_1$ and $\mathbf{AS}_2$ do not agree on the attack from s_1 to y_1 and on the attack from s_2 to y_1. So the group cannot consider that s_1 or s_2 are good vs-defenders for a against y_1.

Note that this behaviour also appears with the merging process proposed in [6].

4 Conclusion

In this paper, we have proposed a new method for merging different argumentation systems in a multi-agent setting. This approach is particularly interesting from a computational point of view because it is a linear process. It is easy to apply and exactly reflects the impact of each agent on the group. It also corrects some disadvantages of the method proposed in [6] (this is, to our knowledge, the only existing method for merging argumentation systems) since it provides only a single output weighted argumentation system.

There are several directions for future works. The first one will be to consider a reliability level for each agent and to take it into account for computing the weights of the interactions for the group. Another extension of this work will address the merging of bipolar argumentation systems, which are systems capable of handling two kinds of interaction, support and attack. For that purpose, a natural idea is to extend the weighted argumentation systems so as to handle positive and negative weights. A positive (resp. negative) weight will apply to a support (resp. an attack). That will lead to the study of bipolar weighted argumentation systems.

[1] For instance because it belongs to all preferred extensions.

References

1. L. Amgoud and C. Cayrol. Inferring from inconsistency in preference-based argumentation frameworks. *Journal of Automated Reasoning*, 29:125–169, 2002.
2. L. Amgoud, Y. Dimopoulos, and P. Moraïtis. A unified and general framework dor argumentation-based negotiation. In *Proc. of AAMAS*, pages 963–970, 2007.
3. L. Amgoud, N. Maudet, and S. Parsons. Arguments, Dialogue and Negotiation. In *Proc of* 14^{th} *ECAI*, pages 338–342, 2000.
4. C. Cayrol, C. Devred, and MC. Lagasquie-Schiex. Acceptability semantics accounting for strength of attacks in argumentation. In *Proc. of ECAI*, pages 995–996, 2010.
5. C. Cayrol and MC. Lagasquie-Schiex. Merging argumentation systems with weighted argumentation systems: a preliminary study. Technical Report RR–2011-18–FR, IRIT, 2011.
6. S. Coste-Marquis, C. Devred, S. Konieczny, MC. Lagasquie-Schiex, and P. Marquis. On the merging of Dung's argumentation systems. *Artificial Intelligence, Argumentation in Artificial Intelligence*, 171(10-15):730–753, 2007.
7. P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence*, 77:321–357, 1995.
8. P. E. Dunne, A. Hunter, P. McBurney, S. Parsons, and M. Wooldridge. Inconsistency tolerance in weighted argument systems. In *Proc of AAMAS*, 2009.
9. J. Fox and S. Parsons. On using arguments for reasoning about values and actions. In *Proc. of AAAI-Symposium on qualitative preferences in deliberation and practical reasoning*, pages 55–63, 1997.
10. T. Gordon and N. Karacapilidis. The zeno argumentation framework. In *Proc. of ICAIL*, pages 10–18. ACM Press, 1997.
11. A. C. Kakas and P. Moraïtis. Argumentation based decision making for autonomous agents. In *Proc. of AAMAS*, pages 883–890, 2003.
12. N. Karacapilidis and D. Papadias. Computer supported argumentation and collaborative decision making: the HERMES system. *Information systems*, 26(4):259–277, 2001.
13. P. Krause, S. Ambler, M. Elvang, and J. Fox. A logic of argumentation for reasoning under uncertainty. *Computational Intelligence*, 11 (1):113–131, 1995.
14. D. C. Martinez, A. J. Garcia, and G. R. Simari. On defense strength of blocking defeaters in admissible sets. In *Proc. of KSEM (LNAI 4798)*, pages 140–152, 2007.
15. D. C. Martinez, A. J. Garcia, and G. R. Simari. An abstract argumentation framework with varied-strength attacks. In *Proc of KR*, pages 135–143, 2008.
16. D. C. Martinez, A. J. Garcia, and G. R. Simari. Strong and weak forms of abstract argument defense. In *Proc of COMMA*, pages 216–227, 2008.
17. S. Parsons, C. Sierra, and N. R. Jennings. Agents that reason and negociate by arguing. *Journal of Logic and Computation*, 8(3):261–292, 1998.
18. H. Prakken and G. Vreeswijk. Logics for defeasible argumentation. In *Handbook of Philosophical Logic*, volume 4, pages 218–319. Kluwer Academic, 2002.
19. B. Verheij. Deflog: on the logical interpretation of prima facie justified assumptions. *Journal of Logic in Computation*, 13:319–346, 2003.