# Some Considerations on Epistemic and Practical Reasoning in Abstract Argumentation

Pietro Baroni and Massimiliano Giacomin

Dep. of Information Engineering, University of Brescia, Brescia, Italy {massimiliano.giacomin,pietro.baroni}@unibs.it

**Abstract.** In this short paper we discuss two approaches for integrating epistemic and practical reasoning in abstract argumentation, showing their commonalities and differences both from a technical and conceptual perspective.

**Keywords:** Abstract Argumentation, Semantics, Epistemic and Practical Reasoning

#### 1 Introduction

Abstract argumentation provides a general account of argumentation where arguments are simply represented as nodes of a directed graph  $AF = (A, \rightarrow)$ , called abstract argumentation framework [7], and binary attacks between them correspond to the edges of the graph, i.e. an argument a attacks an argument b if  $(a,b) \in \rightarrow$ , also denoted as  $a \to b$ . The issue is then to determine a justification status for the arguments in A. To this purpose, several argumentation semantics identify for each argumentation framework a number of extensions, each intuitively conceived as a set of arguments that can survive the conflict together. Most semantics embed a notion of defense, i.e. admissible sets of arguments are required to counterattack the arguments against them, and extensions are defined as admissible sets satisfying additional constraints that reflect the intuitions and the degree of skepticism specific to the semantics [3]. More specifically, a set of arguments  $\mathcal{A}rgs$  is admissible if  $\neg \exists a, b \in \mathcal{A}rgs : a \rightarrow b$ , and for any b such that  $b \to a$  with  $a \in \mathcal{A}rgs$ , there is an argument  $c \in \mathcal{A}rgs$  such that  $c \to b$ . A complete extension is then an admissible set Args including all arguments it defends, i.e. if  $\forall b$  such that  $b \to a$  there is  $c \in Args$  such that  $c \to b$ , then  $a \in \mathcal{A}rqs$ . For the sake of the present paper, we need to recall grounded (GR) and preferred ( $\mathbf{PR}$ ) semantics only. Given an AF, grounded semantics identifies as its unique extension, denoted as  $\mathbf{GR}_{AF}$ , the least (w.r.t.  $\subseteq$ ) complete extension, while preferred semantics identifies as its extensions the maximal (w.r.t.  $\subseteq$ ) complete extensions, denoted as  $\mathcal{E}_{PR}(AF)$ .

Abstract argumentation frameworks capture a variety of reasoning situations, typically based on conflicting information affected by uncertainty and incompleteness. In particular, a distinction has been advocated in [9] between epistemic and practical arguments. While epistemic arguments concern reasoning about what to believe, practical arguments concern reasoning about what

to do, involving goals, desires and intentions. This distinction impacts on the semantics adopted to evaluate argument justification.

On the grounds that conflicts between epistemic arguments mainly arises from uncertainty and incompleteness of information, grounded semantics is proposed in [9] to deal with epistemic arguments, since it enforces a skeptical behavior ensuring that any indecision about arguments prevents their justification. To exemplify this idea, a case concerning how to reach a remote small town is described in [9]. Suppose Mary warns that there will be a railway strike, while Bob does not believe there will be such a strike. Two conflicting arguments  $e_{strike}$  and  $e_{\neg strike}$  then arise and none of them can be justified, thus the question concerning whether the train will be available remains undecided.

Turning to practical arguments, in this case conflicts between them arise from the fact that distinct goals cannot all be fulfilled. The decision can then be based on meta-level considerations, e.g. in the framework of value-based argumentation [6] each argument supports a value and an attack succeeds only if the value supported by the attacked argument is not strictly preferred to the value associated to the attacking argument. Continuing the example above, assume that John has to give a talk in the remote town and, in order to reach it, he can either take the train or drive the car. This situation can be modeled by two mutually conflicting practical arguments  $p_{train}$  and  $p_{car}$ . If the train, differently from the car, allows John to work on a paper he has to submit, then the value supported by  $p_{train}$  (i.e. reaching the destination and working) is strictly preferred w.r.t. the value supported by  $p_{car}$  (i.e. reaching the destination only), thus  $p_{train}$  attacks  $p_{car}$  but not vice versa, and  $p_{train}$  turns out to be justified. This outcome corresponds to a general result in the context of value-based argumentation frameworks, i.e. if values are totally and strictly ordered and there are no attack cycles between arguments supporting the same value, then the resulting framework has a unique grounded and preferred extension [6]. However, when values do not allow to discriminate between conflicting arguments, one is led to make an arbitrary choice between them. On this basis, a very credulous approach is advocated in [9] for practical arguments, i.e. selecting a preferred extension at random. For instance, if the available alternatives for John are the car and a crowded bus (where working on the paper is impossible), then we have two mutually conflicting arguments  $p_{car}$  and  $p_{bus}$ , but differently from the case of  $e_{strike}$  and  $e_{\neg strike}$  either of them should be justified.

The question then arises as to how to manage epistemic and practical arguments combined together. For instance, in the running example John may evaluate the three options corresponding to the train, the car and the (crowded) bus, taking into account the possibility of the railway strike. In the next section we review two approaches for integrating epistemic and practical reasoning, i.e. one introduced by Prakken in [9] and an approach first proposed in [10] and then recasted, as sketched in [8], as an instance of a framework for combining argumentation semantics based on decomposability [1]. The paper then provides a comparison between these approaches and finally outlines some perspectives for further research.

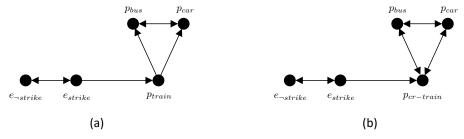


Fig. 1. Representation of the running example and a variation.

## 2 Two approaches for epistemic and practical arguments

#### 2.1 Prakken's approach

As in [9], we assume that the set of arguments A of the AF is partitioned into a set of epistemic arguments  $A_e$  and a set of practical arguments  $A_p$ , where epistemic arguments can attack the practical ones but not viceversa.

The viable practical options are identified in [9] as follows. First, the grounded extension  $\mathbf{GR}_{AF}$  is computed, then all arguments that are attacked by epistemic arguments that are not in turn attacked by (arguments of)  $\mathbf{GR}_{AF}$  are removed from A. Finally, each practical option is derived from a preferred extension of the resulting argumentation framework.

Figure 1(a) depicts the argumentation framework modeling John's problem where the options of taking the train, taking the crowded bus and driving the car are considered, and the contradictory epistemic arguments concerning the strike are taken into account. In this case,  $\mathbf{GR}_{AF} = \emptyset$ , leading to remove  $e_{strike}$ ,  $e_{\neg strike}$  and  $p_{train}$ . Thus, the resulting preferred extensions are  $\{p_{bus}\}$  and  $\{p_{car}\}$ , i.e. either the bus or the car should be chosen. Note that without argument  $e_{strike}$ , the unique preferred extension would be  $\{e_{\neg strike}, p_{train}\}$ , i.e. the train should be chosen since it allows John to work while traveling.

#### 2.2 Decomposability-based approach

The formal treatment of this approach requires a labelling-based definition of argumentation semantics, where each extension E is replaced by a corresponding labelling, i.e. a total function from A to  $\{in, out, undec\}$ , such that an argument a is labelled in iff  $a \in E$ ; it is labelled out iff  $\exists b \in E$  such that  $b \to a$ ; it is labelled undec if neither of the above conditions holds. Thus, a semantics S returns for any AF a set of labellings  $\mathcal{L}_{S}(AF)$  instead of a set of extensions.

Given an  $AF = (A, \to)$ , the general approach to combine semantics introduced in [8] considers a partition  $\mathcal{P} = \{P_1, \dots, P_n\}$  of A with associated semantics  $S(P_i)$ . Each set  $P_i$  identifies the sub-framework  $AF\downarrow_{P_i} = (P_i, \to \cap (P_i \times P_i))$ , where the semantics  $S(P_i)$  is locally applied. The local computation of  $S(P_i)$  is expressed by a local function  $F_{S(P_i)}$ , which assigns to the arguments in  $P_i$  a set of labellings on the basis of  $AF\downarrow_{P_i}$ , of the set  $P_i^{\text{inp}} = \{a \notin P_i \mid \exists b \in P_i : a \to b\}$  including the external arguments attacking  $P_i$  (playing the role of input arguments), of the labels externally assigned to them  $(\bigcup_{j=1...n,j\neq i} \mathcal{L}ab_{P_j})\downarrow_{P_i^{\text{inp}}}$ , and of the attack relation  $P_i^R = \to \cap (P_i^{\text{inp}} \times P_i)$  from the input arguments of  $P_i^{\text{inp}}$  to  $P_i$ . Then the resulting labelling are  $\{\mathcal{L}ab_{P_1} \cup \ldots \cup \mathcal{L}ab_{P_n} \mid \mathcal{L}ab_{P_i} \in F_{S(P_i)}(AF\downarrow_{P_i}, P_i^{\text{inp}}, (\bigcup_{j=1...n,j\neq i} \mathcal{L}ab_{P_j})\downarrow_{P_i^{\text{inp}}}, P_i^R)\}$ .

<sup>&</sup>lt;sup>1</sup> More precisely, given a labelling  $\mathcal{L}$  and a set of arguments  $\mathcal{A}rgs$ ,  $\mathcal{L}\downarrow_{\mathcal{A}rgs} \triangleq \mathcal{L}\cap(\mathcal{A}rgs \times \{\text{in}, \text{out}, \text{undec}\})$ .

In order to apply this general schema to epistemic and practical arguments, we consider the partition  $\{A_e, A_p\}$  with  $S(A_e) = \mathbf{GR}$  and  $S(A_p) = \mathbf{PR}$  (note however that the framework can easily be generalized to other semantics). As shown in [1], the relevant local functions can be identified by applying each semantics  $\mathcal{S}$  to a standard argumentation framework where the input arguments are added to  $AF\downarrow_{P_i}$  and the input labelling is enforced through the addition of arguments attacking out-labelled arguments and self-attacks for all undeclabelled arguments.

For instance, Figure 1(b) depicts an argumentation framework representing a variation of the running example where also the train is crowded (and thus does not allow John to work), and as a consequence the three options are equally preferable. The application of  $\mathbf{GR}$  to  $AF\downarrow_{\{e_{strike},e_{\neg strike}\}}$  (with empty input arguments) yields both epistemic arguments undecided. Thus, the local application of  $\mathbf{PR}$  to  $AF\downarrow_{\{p_{cr-train},p_{bus},p_{car}\}}$  yields the two preferred labellings  $\{(p_{cr-train}, \mathtt{undec}), (p_{bus}, \mathtt{in}), (p_{car}, \mathtt{out})\}$  and  $\{(p_{cr-train}, \mathtt{undec}), (p_{bus}, \mathtt{out}), (p_{car}, \mathtt{in})\}$ . It can be checked that Prakken's approach gives the same outcome, identifying as extensions the sets  $\{p_{bus}\}$  and  $\{p_{car}\}$ . Intuitively, since the availability of the train is uncertain, either the train or the car should be considered.

# 3 Comparing the two approaches

In order to analyze the relationship between the two approaches, it is convenient to partition the arguments of A on the basis of the labelling assigned by  $\mathbf{GR}$  applied to the whole AF. In particular, we partition  $A_e$  into  $\mathbf{in}_e$ ,  $\mathsf{out}_e$  and  $\mathsf{undec}_e$ , where  $l_e$  denotes the subset of  $A_e$  including arguments labelled l according to  $\mathbf{GR}$ . We also partition  $A_p$  into  $\mathbf{in}_p$ ,  $\mathsf{out}_p$ ,  $\mathsf{undec}_p^{\leftarrow e}$  and  $\mathsf{undec}_p^{\sim}$ , where  $\mathbf{in}_p$  and  $\mathsf{out}_p$  have the same meaning as above,  $\mathsf{undec}_p^{\leftarrow e}$  includes those arguments of  $A_p$  that are labelled  $\mathsf{undec}_p$  includes the remaining arguments of  $A_p$  that are labelled  $\mathsf{undec}_e$ .

The following observations concerning Prakken's approach are relatively easy to prove: i)  $\operatorname{out}_e$ ,  $\operatorname{undec}_e$ ,  $\operatorname{out}_p$  and  $\operatorname{undec}_p^{\leftarrow e}$  are removed from A, thus they do not belong to any preferred extension; ii)  $\operatorname{in}_e$  and  $\operatorname{in}_p$  belong to all preferred extensions. A direct consequence of the first observation is that after removal  $\operatorname{undec}_p^{\sim}$  does not receive attacks from external arguments, and due to the property of directionality of  $\operatorname{PR}$  [4] the set of preferred extensions is  $\{\operatorname{in}_e \cup \operatorname{in}_p \cup E \mid E \in \mathcal{E}_{\operatorname{PR}}(AF \downarrow_{\operatorname{undec}_n^{\sim}})\}$ .

As to the decomposability-based approach, using the results in [1] it is possible to prove that a corresponding outcome is yielded for all arguments but  $\mathtt{undec}_p^{\sim}$ . In particular, any obtained labelling assigns the label in to the arguments in  $\mathtt{in}_e$  and  $\mathtt{in}_p$ , the label out to the arguments in  $\mathtt{out}_e$  and  $\mathtt{out}_p$ , and the label  $\mathtt{undec}$  to the arguments in  $\mathtt{undec}_e$  and  $\mathtt{undec}_p^{\leftarrow}e$ . Differences only concern the arguments of  $\mathtt{undec}_p^{\sim}$ . Taking into account decomposability of  $\mathbf{PR}$  [1], it can be shown that the labellings restricted to  $\mathtt{undec}_p^{\sim}$  can be obtained by locally applying  $\mathbf{PR}$  into the argumentation framework  $AF \downarrow_{\mathtt{undec}_p^{\sim}}$  by taking into account the input arguments of  $\mathtt{undec}_p^{\sim}$  in  $\mathtt{undec}_p^{\leftarrow}e$ . Due to a monotony prop-

erty of the local function of preferred semantics, it can be shown that for any labelling obtained by the decomposability-based approach there is an extension of Prakken's approach which (not necessarily strictly) includes all arguments labelled in. Intuitively, the decomposability-based approach is more skeptical wrt Prakken's proposal.

From a conceptual point of view, this difference can be appreciated in the case of Figure 1(a), where the decomposability-based approach returns a unique labelling with all arguments undecided. While this may seem undesirable, we believe the outcome more closely corresponds to the direction of the attacks. In particular, while in Figure 1(b) there is no preference towards the train and thus it is perfectly sensible to choose between the car and the bus, in the case of Figure 1(a) leaving the train out of consideration would prevent a possible alternative which is strictly more preferred than the car and the bus.

## 4 Perspectives for further research

We believe the considerations pointed out in this short paper open the way to several interesting investigations. A first direction is applying different semantics besides **GR** and **PR**, such as [2]. Another interesting question is how to handle a gradual evaluation of practical arguments given different degrees of strength for epistemic arguments, possibly exploiting a probabilistic approach [5].

## References

- P. Baroni, G. Boella, F. Cerutti, M. Giacomin, L. W. N. van der Torre, and S. Villata. On the input/output behavior of argumentation frameworks. *Artificial Intelligence*, 217:144–197, 2014.
- 2. P. Baroni and M. Giacomin. Resolution-based argumentation semantics. In Frontiers in Artificial Intelligence and Applications, pages 25–36, 2008.
- 3. P. Baroni and M. Giacomin. Skepticism relations for comparing argumentation semantics. *Int. Journal of Approximate Reasoning*, 50(6):854–866, 2009.
- 4. P. Baroni, M. Giacomin, and B. Liao. On topology-related properties of abstract argumentation semantics. A correction and extension to *Dynamics of argumentation systems: A division-based method. Artif. Intell.*, 212:104–115, 2014.
- P. Baroni, M. Giacomin, and P. Vicig. On rationality conditions for epistemic probabilities in abstract argumentation. In Frontiers in Artificial Intelligence and Applications, pages 121–132, 2014.
- T.J.M. Bench-Capon. Persuasion in practical argument using value-based argumentation frameworks. *Journal of Logic and Computation*, 13(3):429–448, 2003.
- 7. P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming, and n-person games. *Artif. Intell.*, 77(2):321–357, 1995.
- M. Giacomin. Handling heterogeneous disagreements through abstract argumentation (extended abstract). In Proc. of PRIMA 2017, pages 3–11, 2017.
- 9. H. Prakken. Combining sceptical epistemic reasoning with credulous practical reasoning. In *Proc. of COMMA 2006*, pages 311–322. IOS Press, 2006.
- T. Rienstra, A. Perotti, S. Villata, D.M. Gabbay, and L. van der Torre. Multi-sorted Argumentation, pages 215–231. Springer Berlin Heidelberg, 2012.