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A general semi-structured formalism for computational argumentation: Definition, properties, and examples of application

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ABSTRACT

In the field of computational argumentation several formalisms featuring different levels of abstraction and focusing on different aspects of the argumentation process have been developed. Their combined use, necessary to achieve a comprehensive formal coverage of the argumentation phenomenon, gives rise to a nontrivial interplay between different abstraction levels, so that counterintuitive or undesirable outcomes may result from the combination of formalisms which appear to be well-behaved when considered in isolation. To address this problem we introduce a semi-structured formalism for argumentation, called *LAF*-ensembles, capturing a set of essential features of structured arguments and define a class of set based argumentation frameworks appropriate to support a semantic assessment of arguments for *LAF*-ensembles. It is shown that, under suitable assumptions, the combination of a *LAF*-ensemble and of an appropriate argumentation framework is guaranteed to produce justification outcomes satisfying a set of essential requirements. The generality and usefulness of the proposed approach are demonstrated by illustrating its ability to capture as instances and enhance two structured argumentation formalisms from the literature, namely Vreeswijk's abstract argument systems and Modgil and Prakken's *ASPIC*$^{+}$. In particular, a revised version of the latter formalism, properly dealing with generic contrariness and solving significant technical limitations of *ASPIC*$^{+}$, is proposed.

1. Introduction

In the last decades computational argumentation has emerged as a powerful approach to the study of reasoning in the presence of incomplete and conflicting information with a wide range of applications in AI [1,2]. In this context several formalisms at various levels of abstraction have been developed, in order to support the investigation of general and reusable properties, valid for all the instances of a given abstract model.

At the highest abstraction level, internal properties of arguments are ignored and only their relationships are considered. This is exemplified by the well-known formalism of argumentation frameworks proposed by Dung [3], focused on a binary relation of attack between arguments, and by subsequent proposals like bipolar argumentation frameworks [4], where a support relation is also considered, and Abstract Dialectical Frameworks [5], capturing a generic notion of dependence among

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arguments. In these works, the main interest is typically on assessing the acceptance or justification status of arguments on the basis of their relationships and according to some criteria formalized by the notion of *argumentation semantics*.

Structured argumentation formalisms [6] can be regarded as less abstract as they provide some details of how arguments are built and, accordingly, of how and why they relate (and, in particular, attack) each other, possibly leaving unspecified or partially specified other aspects, e.g. the actual language used to build arguments or the preference relation (if any) holding over them.

It is rather common that in a structured argumentation formalism the assessment of the acceptance or justification status of the produced arguments is achieved by resorting to a more abstract representation. For instance, given a set of structured arguments where some attack relation is identified, one may first produce a corresponding argumentation framework, where everything but the attack relation is ignored, then apply an argumentation semantics to identify the *accepted abstract arguments*, and finally project back the results so as to identify the corresponding *accepted structured arguments*.

This gives rise to a nontrivial interplay among concepts and properties defined at the different levels of abstraction. In the example above, the properties of the set of accepted structured arguments depend in some way on the set of accepted abstract arguments, which in turn depends on the argumentation semantics applied and on the argumentation framework built, which in turn depends on the correspondence drawn between the structured level and its abstract representation and on the notion of attack adopted.

If, in the end, something goes wrong, i.e. the set of accepted structured arguments has some undesirable features, it may not be obvious to 'find the culprit' (or anyway to find the best way to fix the problem) among the many assumptions and technical choices involved in the various steps of this process, all of which may sound reasonable when considered in isolation, but whose combination may turn out not to work well.

This calls for the study of a set of properties, spanning across the different abstraction levels of an argumentation system, which are able altogether to guarantee that such problems do not arise.

This kind of investigation has been pioneered by the work in [7] where it is pointed out that several argumentation systems fail to comply with a set of basic desirable properties, called *rationality postulates*, and it is shown how to guarantee that they are satisfied for a class of rule-based argumentation systems using a language equipped with classical negation.

Recently, it has been shown in [8] that the technical solutions proposed in [7] may run into troubles when considering a language equipped with a generic contrariness relation, rather than classical negation, and the need for a novel approach suitable to this generalized context has been evidenced.

Moreover, the definition of these postulates and even more the technical solutions proposed to guarantee their satisfaction are formalism specific and their extension to other classes of argumentation systems, like Vreeswijk's abstract argumentation systems [9], has not been investigated yet and represents an open problem.

To provide a comprehensive answer to these research issues we adopt the standpoint that both postulates and solutions are investigated at a higher level of abstraction with an approach that is as formalism independent as possible. In this way we not only ensure generality and wider applicability of the achieved results but also that they are, in a sense, more robust since they rely (explicitly or implicitly) on less specific assumptions and, by construction, must be valid in a larger variety of cases. To this purpose, we introduce a semi-structured argumentation formalism, called *LAF*-ensembles, which captures a set of essential features of structured arguments, while not being committed to any specific way of actually building them. Following this line, we propose a set of requirements which generalize to *LAF*-ensembles those already introduced in the literature and a general method, resorting to set based argumentation frameworks, to guarantee the satisfaction of these requirements. We stress that the proposed requirements represent a generalization rather than a modification of similar ideas already presented in the literature, lying at a novel abstraction level. The choice of this abstraction level turns out to be a key factor in the identification of the general well-founded solution we propose, which instead includes several original aspects with respect to previous literature. The approach is validated by applying it to two argumentation formalisms, namely Vreeswijk's abstract argumentation systems [9] and $ASPIC^+$ [10], and showing that it is not just able to capture them as instances but, more importantly, to support the identification of significant problems and the definition of proper solutions, based on the underlying general principles. In particular, we propose a revised version of $ASPIC^+$ which on the one hand turns out to be more expressive, as it deals properly with any form of contrariness relation, and on the other hand is conceptually and technically more solid, as it avoids the limitations and some undesirable side-effects of the previous solution, even in the case of classical negation. Moreover the approach is able to reveal inter-formalism relationships as we show by identifying a previously unknown correspondence between Vreeswijk's approach and Dung's semantics.

These results support the claim that the main contribution of the paper is introducing and validating a novel general formal tool supporting the analysis, revision, and possibly design from scratch of argumentation systems, applicable to a virtually unlimited range of diverse actual argumentation formalisms.

The paper is organized as follows.

After recalling some necessary background in Section 2, we introduce *LAF*-ensembles in Section 3. To ensure generality, *LAF*-ensembles make very limited assumptions on the underlying language, which is not required to be closed with respect to classical negation but is only assumed to be equipped with a set-level inhibition function, satisfying some very mild constraints.

On these bases, we define in Section 4 a generic notion of argument justification and specify some fundamental requirements for it. We then identify in Section 5 a fundamental property for *LAF*-ensembles, called *inhibition infallibility consonance*