Formalizing Processes in Defeasible Argumentation using Labeled Deductive Systems

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Keywords: defeasible argumentation, argumentation frameworks, labeled deductive systems

1 Introduction and motivations

Defeasible argumentation [SL92,CML00,PV99] has proven to be a successful approach to finding a suitable formalization for reasoning with incomplete and potentially inconsistent information. In recent years there has been an increasing demand for a variety of logical systems for tackling this problem, prompted mostly by applications of logic in AI, logic programming and other related areas.

The study and development of argumentative frameworks has deserved special attention in this regard, since argumentation constitutes a confluence point for characterizing traditional approaches to non-monotonic reasoning systems, such as Gelfond's extended logic programming and Reiter's default logic [BDKT97]. In that context, Labeled Deductive Systems (LDS) [Gab96] emerged as an interesting alternative that provides a flexible methodology to formalize complex logical systems.

This paper summarizes the main results developed in the author's PhD Thesis [Che01]. The main goal of the Thesis is to provide a formalization of defeasible argumentation oriented towards its computational treatment. In order to do this, an LDS-based logical framework for defeasible argumentation called LDS_{ar} has been developed. The object language is that of *logic programming*, complemented with labels that identify distinguished elements for representing knowledge and performing inference.

2 An LDS-based framework for defeasible argumentation

The study of logical properties of defeasible argumentation, particularly those related to the MTDR and DeLP frameworks [SCG94,Gar00], motivated the development of LDS_{ar} [Che01], a unified logical formalism for defeasible argumentation based on the *labelled deduction* methodology [Gab96]. In labelled deduction, the usual notion of formula is replaced by the notion of *labelled formula*, expressed as *Label*:*f*, where *Label* represents a label associated with the wff *f*. A labelling language $\mathcal{L}_{Label}$ and knowledge-representation language $\mathcal{L}_{kr}$ can be combined to provide a new, labelled language, in which labels convey additional information also encoded at the object-language level. Formulas are labelled according to a family of *deduction rules*, and with agreed ways of propagating labels via the application of these rules.

In LDS_{ar}, the language $\mathcal{L}_{kr}$ is that of extended logic programming. Labels extend this language by distinguishing defeasible and non-defeasible information. A consequence relation $\mid\!\sim_{Arg}$ propagates labels, implementing the SLD resolution procedure along with a consistency check every time new defeasible information is introduced in a proof. This information is collected into a *support set*, containing all defeasible information needed to conclude a given formula. Thus, arguments are modeled as labelled formulas $\mathcal{A}{:}h$, where $\mathcal{A}$ stands for a set of (ground) clauses, and h for an extended literal.

Given a knowledge base Γ the consequence relation $\mid\!\sim_{Arg}$ allows the inference of labelled formulas of the form *argument:literal*. Given an argument A there may be *counterarguments* $B_1 \ldots B_n$ which *defeat* A. These defeaters can, on its turn, be defeated. This results in a recursive characterization, called *dialectical tree* [SCG94], in which arguments correspond to nodes of the tree, and the root corresponds to the main argument in question. If that main argument remains ultimately undefeated, it is called a *warranted argument*, or just *warrant*.

In order to capture this situation, a new, extended consequence relationship $\mid\!\sim_{\mathcal{T}}$ is defined. Those wffs derivable from Γ via $\mid\!\sim_{\mathcal{T}}$ will correspond to dialectical trees, having the form *dialectical tree*:*conclusion*. A marking procedure [SCG94] allows us to determine whether the root of the tree is a warranted argument or not.

3 Main contributions of the Thesis

LDS_{ar} provides a useful formal framework for studying logical properties of defeasible argumentation in general, and of DeLP [Gar00] in particular. Equivalence results with other argumentative frameworks were also studied, particularly those relating DeLP with other LP-based formalisms.

Cummulativity was proven to hold for argumentative formulae. This allows us to think of a knowledge base as a set of 'atomic' arguments (facts and rules), which can be later on extended by incorporating new, more complex arguments. This feature makes it easier to formalize *dialectical databases*, a TMS-based approach to defeasible argumentation which is currently being explored [CCS00]. Cummulativity is proven *not* to hold for warranted conclusions, following the intuitions suggested by Prakken & Vreeswijk [PV99].

Superclassicality was shown to hold for both argument construction and warrant with respect to SLD resolution. In other words, if $Th_{sld}(\Gamma)$ denotes the set of conclusions that can be obtained from Γ via SLD, then it holds that $C_{arg}(\Gamma) \subseteq Th_{sld}(\Gamma)$ and $C_{war}(\Gamma) \subseteq Th_{sld}(\Gamma)$, where C_{arg} and C_{war} stand for the consequence operator for argument construction and warrant, respectively. This implies, among other things, that the analysis of attack between arguments can be focused on those literals present in defeasible rules. Analogously, the property of "right weakening" is proven to hold for both C_{arg} and C_{war}. This implies that (warranted) arguments with a conclusion x are also (warranted) arguments for y whenever $y \leftarrow x$ is present as a strict, non-defeasible rule.

Another interesting issue concerns the definition of *variants* for LDS_{ar}. Since LDS_{ar} is a logical framework, its knowledge-encoding capabilities are determined by the underlying logical language, whereas the inference power is characterized by its natural deduction rules. Adopting a different KR language or modifying the existing inference rules will lead to different variants of LDS_{ar}. Thus, for instance, adopting a full first-order language will lead to a logical system with a behavior similar to the SL framework [SL92]. On the other hand, restricting the KR language to Horn clauses will result in a formulation closer to normal logic programming (NLP) under well-founded semantics.These variants are directly related to some existing argumentation frameworks, such as Simari-Loui's [SL92], MTDR [SCG94], DeLP [Che01] and NLP (normal logic programming conceptualized in an argumentative setting as suggested in [BDKT97]). Two distinguished variants of DeLP deserved particular attention, namely those restricting DeLP to default and strict negation, respectively. The relation between these variants of DeLP and normal logic programming was explored [CDSS00]. Different criteria under which both strict and defeasible rules could be rewritten into a simpler but semantically equivalent form were defined.

The notion of dialectical tree has proven to be very useful for capturing different aspects of the process of argumentation. It should be remarked that similar approaches have been recently tried in other formalisms (see for example [Pra00]). A formal analysis proved that dialectical trees can be pruned (following the procedure introduced in [SCG94]) without affecting the marking procedure. An equivalence theorem between top-down and bottom-up computation of dialectical trees was also established.

4 Conclusions

During the last decade, a 'clash of intuitions' has appeared within the argumentation community [CML00,PV99], where different, alternative approaches have been proposed. As we have briefly sketched in this paper, having a logical formalism such as LDS_{ar} makes it easier to analyze, compare and relate different features associated with existing argumentative frameworks, providing at the same time a test-bed for studying other related issues (such as argumentation protocols, resource-bounded reasoning, etc.). These aspects are directly related to formalizing multiagent environments, in which argumentation plays a major role when modeling the communicative and reasoning abilities of the agents involved. Research in this direction is currently being pursued.

References

[BDKT97] Bondarenko, A., Dung, P., Kowalski, R., and Toni, F. An abstract, argumentation-theoretic approach to default reasoning. *Artificial Intelligence 93*, 1-2 (1997), 63–101.

[CCS00] Capobianco, M., Chesñevar, C. I., and Simari, G. R. A Formalization of Dialectical Bases for Defeasible Logic Programming. In *Proceedings of the 6th Internacional Congress of Informatics Engineering* (Capital Federal, April 2000), Universidad Buenos Aires.

[CDSS00] Chesñevar, C. I., Dix, J., Stolzenburg, F., and Simari, G. R. Relating Defeasible and Normal Logic Programming through Transformation Properties. *Theoretical Computer Science (submitted)* (2000).

[Che01] Chesñevar, C. I. *Formalización de los Procesos de Argumentación Rebatible como Sistemas Deductivos Etiquetados.* PhD thesis, Departamento de Ciencias de la Computación, January 2001.

[CML00] Chesñevar, C. I., Maguitman, A., and Loui, R. Logical Models of Argument. *ACM Computing Surveys 32*, 4 (December 2000), 337–383.

[Gab96] Gabbay, D. *Labelling Deductive Systems (vol.1).* Oxford University Press (Volume 33 of Oxford Logic Guides), 1996.

[Gar00] García, A. J. *Programación en Lógica Rebatible: Lenguaje, Semántica Operacional y Paralelismo.* PhD thesis, Dep. de Cs. de la Computación, Universidad Nacional del Sur, December 2000.

[Pra00] Prakken, H. Relating protocols for dynamic dispute with logics for defeasible argumentation. *Synthese (to appear)* (2000).

[PV99] Prakken, H., and Vreeswijk, G. Logics for Defeasible Argumentation. In *Handbook of Philosophical Logic*, D. Gabbay, Ed. Kluwer Academic Publisher, 1999.

[SCG94] Simari, G. R., Chesñevar, C. I., and García, A. J. The role of dialectics in defeasible argumentation. In *Anales de la XIV Conferencia Internacional de la Sociedad Chilena para Ciencias de la Computación* (November 1994), Universidad de Concepción, Concepción (Chile).

[SL92] Simari, G. R., and Loui, R. P. A Mathematical Treatment of Defeasible Reasoning and its Implementation. *Artificial Intelligence 53* (1992), 125–157.