Argumentation-Based Defeasible Reasoning For Existential Rules

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Abstract

Logic based argumentation allows for defeasible reasoning over monotonic logics. In this paper, we introduce **DEFT**, a tool implementing *argumentative defeasible reasoning over existential rules*. We explain how DEFT overcomes derivation loss and discuss DEFT's empirical behavior.

Research Context

We are interested in argumentation based defeasible reasoning (Dung 1995; Prakken and Sartor 1997; García and Simari 2004) for *existential rules*, a first order logic subset employed for sharing, reuse and reasoning over large databases on the Semantic Web (SW) (Calì, Gottlob, and Lukasiewicz 2012) and we focus on the tractable fragments of existential rules, $Datalog^{\pm}$ (Calì, Gottlob, and Lukasiewicz 2012). Defeasible $Datalog^{\pm}$ was proposed in (Martinez et al. 2014; Deagustini et al. 2015) but it *does not account for the possibility of loss* of deduced information that can *render the reasoning process non deterministic*. We improve upon the state of the art by proposing a new hypergraph-based algorithm that will prevent derivation loss.

The contribution of the paper is to provide the *first argumentation based tool* for defeasible $Datalog^{\pm}$ in the literature: DEFT (Defeasible Datalog$^{\pm}$ Tool) and compare its behavior with respect to argumentation tools in the literature relevant for defeasible reasoning with ambiguity propagation: ASPIC+ (Prakken 2010) with its grounded semantics (Governatori et al. 2004) and DeLP (García and Simari 2004) with its dialectical trees.

Chase Derivation Loss

Defeasible $Datalog^{\pm}$ extends $Datalog^{\pm}$ to include defeasible facts and defeasible rules. $Datalog^{\pm}$ refers to the decidable fragment of existential rules (Calì, Gottlob, and Lukasiewicz 2012) that extends the Datalog language with *existential variables* in the rule head. Defeasible reasoning in this context is based on dialectical trees, which, in turn, are based on the classical notion of *derivation* (i.e. the successive application of a set of rules on a set of facts). *The rule application mechanism is called the chase.* The chase procedure is equipped with a restriction test, called derivation reducer, for detecting when the rule application becomes redundant. In the literature several chases are studied (Baget et al. 2014). Here we only restrict ourselves to the derivation reducer used for the Restricted chase (Fagin et al. 2005). Using a derivation reducer may induce a loss of rule applications depending on the order in which rules are applied. While the order of applications does not impact the final model of the saturated knowledge base (and thus entailment in $Datalog^{\pm}$), it does **affect the set of extracted derivations**. This is important since dialectical-tree-based defeasible reasoning relies on **the set of extracted derivations**.

To allow for lossless derivation extraction we use an adapted combinatorial structure called Graph of Atom Dependency (GAD). This structure can be seen as an improvement over the chase graph (Calì, Gottlob, and Lukasiewicz 2012) that allows *keeping track of all the generated atoms during the chase procedure*. In the GAD the nodes correspond to facts and the labelled directed hyperedges to the rule applications. The intuition behind the use of the GAD is that, for a given GAD and a given atom, there is a *one-to-one mapping, up to derivation equivalence*, between the set of hyperpaths to an atom f and the set of derivations to f. The problem of obtaining all minimal derivations of f can thus be transformed into the problem of generating all minimal hyperpaths of f in the GAD. For every hyperpath of the GAD we can construct a derivation, and for every derivation there exists a hyperpath. This ensures soundness and completeness of all minimal derivations extraction.

Let us present the chase-based implementation of defeasible $Datalog^{\pm}$ called "DEFT". DEFT uses the GAD structure and relies on the $Datalog^{\pm}$ dedicated inference engine called "GRAAL" (Baget et al. 2015) that accepts a wide variety of formats (OWL2, RuleML and the $Datalog^{\pm}$ format DLGP (Baget et al. 2015)). We run the restricted chase using the GRAAL framework in order to create the GAD.

Results and discussion

By using the GAD structure, DEFT is the first sound and complete $Datalog^{\pm}$ defeasible reasoning tool in the literature. The $Datalog^{\pm}$ features impose a dedicated tool due to two main aspects. First, $Datalog^{\pm}$ allows for existential rules, which neither ASPIC+ nor DeLP can handle since they cannot express existential variables. This can easily be checked by trying to answer the query $q(a, a)$ with the rule

$p(X) \rightarrow q(X,Y)$ and the fact $p(a)$ using online tools like ASPIC argumentation engine demo[1] or DeLPclient[2]. The query is entailed if the system does not support existential rules (as the Y variable is mapped to all known constants). Second, since $Datalog^{\pm}$ allows for weak negation but not classic negation in the body of rules, DEFT can simply use a fast chase mechanism, whereas existing argumentation-based reasoning tools rely on resolution-based inference mechanisms (Bryant and Krause 2008) since they account for classic negation, which induces a **large computational overhead**.

We conducted an empirical evaluation of DEFT in order to measure its performance w.r.t to DeLP and ASPIC+ [3]. The experiments are built upon a pre-established defeasible reasoning benchmark proposed in (Maher et al. 2001). The benchmark we consider is composed of 5 parameterized knowledge bases (also known as theories): **Chain Theory** tests performance when faced with a simple chain of rules; **Circle Theory** tests infinite loops (cycles), **Levels and Trees Theories** test a large number of arguments with small derivations and **Teams Theory** tests performance w.r.t. a sizeable number of conflicts. The results are shown in the table below.

The salient points of this evaluation are two-fold. First, DEFT is the **only tool able to reason with the class of existential rules guaranteed to stop in forward chaining** (namely, Finite Expansion Set (Baget et al. 2014)). Second, DEFT **out-performs existing argumentation-based defeasible reasoning tool** for general logical fragments with only weak negation.

In future work we plan to investigate the semantic relation between defeasible $Datalog^{\pm}$ and the floating conclusions from the work of (Arioua and Croitoru 2016). We also plan to use DEFT in human reasoning akin frameworks for irrationality (Bisquert et al. 2016b; 2016a).

Table 1: Execution time in seconds

Theory		Size	DEFT	ASPIC+	DeLP
$chain(n)$	$n = 100$	201	**0.02**	0.16	0.97
	$n = 400$	801	**0.04**	23.57	31.01
	$n = 800$	1601	**0.08**	∞	254.96
	$n = 2000$	4001	**0.28**	∞	$T.O.$
$circle(n)$	$n = 100$	201	**0.02**	∞	0.99
	$n = 400$	801	**0.04**	∞	49.88
	$n = 800$	1601	**0.06**	∞	$T.O.$
	$n = 2000$	4001	**0.25**	∞	$T.O.$
$levels(n)$	$n = 25$	261	0.02	0.02	169.94
	$n = 4000$	40011	**1.09**	23.22	$T.O.$
	$n = 8000$	80011	**2.08**	115.68	$T.O.$
	$n = 11000$	110011	**2.83**	$T.O.$	$T.O.$
$teams(n)$	$n = 2$	232	0.09	**0.02**	6.93
	$n = 3$	808	0.36	**0.13**	$T.O.$
	$n = 4$	3196	**3.08**	10.50	$T.O.$
	$n = 5$	15016	**25.99**	133.73	$T.O.$
$trees(n,k)$	$n = 3, k = 5$	311	0.10	0.10	227.38
	$n = 5, k = 5$	7811	**2.14**	109.36	$T.O.$
	$n = 6, k = 5$	39061	$T.O.$	$T.O.$	$T.O.$

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References

Arioua, A., and Croitoru, M. 2016. A dialectical proof theory for universal acceptance in coherent logic-based argumentation frameworks. In *ECAI*, volume 285, 55–63. IOS Press.

Baget, J.-F.; Garreau, F.; Mugnier, M.-L.; and Rocher, S. 2014. Extending acyclicity notions for existential rules. In *ECAI*, 39–44.

Baget, J.-F.; Leclère, M.; Mugnier, M.-L.; Rocher, S.; and Sipieter, C. 2015. Graal: A toolkit for query answering with existential rules. In *International Symposium on Rules and Rule Markup Languages for the Semantic Web*, 328–344. Springer.

Bisquert, P.; Croitoru, M.; de Saint-Cyr, F. D.; and Hecham, A. 2016a. Formalizing cognitive acceptance of arguments: Durum wheat selection interdisciplinary study. *Mind and Machines (to appear)*.

Bisquert, P.; Croitoru, M.; de Saint-Cyr, F. D.; and Hecham, A. 2016b. Substantive irrationality in cognitive systems. In *Proceedings of ECAI 2016*.

Bryant, D., and Krause, P. 2008. A review of current defeasible reasoning implementations. *The Knowledge Engineering Review* 23(03):227–260.

Calì, A.; Gottlob, G.; and Lukasiewicz, T. 2012. A general datalog-based framework for tractable query answering over ontologies. *Web Semantics: Science, Services and Agents on the World Wide Web* 14:57–83.

Deagustini, C.; Martinez, M.; Falappa, M.; and Simari, G. 2015. On the influence of incoherence in inconsistency-tolerant semantics for datalog±.

Dung, P. M. 1995. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial intelligence* 77(2):321–357.

Fagin, R.; Kolaitis, P. G.; Miller, R. J.; and Popa, L. 2005.

[1] `http://aspic.cossac.org/ArgumentationSystem/`

[2] `http://lidia.cs.uns.edu.ar/delp_client/`

[3] We used DeLP implementation in Tweety1.7 libraries and an author provided implementation for ASPIC+.

Data exchange: semantics and query answering. *Theoretical Computer Science* 336(1):89–124.

García, A. J., and Simari, G. R. 2004. Defeasible logic programming: An argumentative approach. *Theory and practice of logic programming* 4:95–138.

Governatori, G.; Maher, M. J.; Antoniou, G.; and Billington, D. 2004. Argumentation semantics for defeasible logic. *Journal of Logic and Computation* 14(5):675–702.

Maher, M. J.; Rock, A.; Antoniou, G.; Billington, D.; and Miller, T. 2001. Efficient defeasible reasoning systems. *International Journal on Artificial Intelligence Tools* 10(04):483–501.

Martinez, M. V.; Deagustini, C. A. D.; Falappa, M. A.; and Simari, G. R. 2014. Inconsistency-tolerant reasoning in datalog± ontologies via an argumentative semantics. In *IBERAMIA 2014*. Springer. 15–27.

Prakken, H., and Sartor, G. 1997. Argument-based extended logic programming with defeasible priorities. *Journal of applied non-classical logics* 7(1-2):25–75.

Prakken, H. 2010. An abstract framework for argumentation with structured arguments. *Argument and Computation* 1(2):93–124.