Ontology Reasoning and Evolution with Inconsistency Tolerance

An Argumentative Approach to Revision of Description Logics

Martín O. Moguillansky
CONICET, AI R&D Lab (LIDIA), Universidad Nacional del Sur (UNS), Bahía Blanca, Argentina.
e-mail: mom@cs.uns.edu.ar

Reasoning and change over inconsistent ontologies (i-ont(s)) is of utmost relevance in sciences like medicine and law. Argumentation may be an appropriate formalism to cope with both problems: *(reasoning)* through an argumentation framework (AF) constructed from the i-ont, and *(change)* by handling the dynamics of its arguments. We propose a new family of abstract AFs referred as generalized (GenAF), due to its ability of adapting to different representation languages. Afterwards, we propose a possible instantiation of the GenAF's abstract language for arguments to the basic $\mathcal{ALC}$ description logic for reasoning over i-onts. For dynamics of arguments, a revision operation modifies the graph of arguments in an AF for provoking the argumentation semantics to accept an argument. Thus, revising an $\mathcal{ALC}$-GenAF would introduce a novel methodology for handling evolution of i-onts. To such end, we propose a revision operation by relying upon classic belief revision theory, although contrary to it, consistency restoration is avoided in order to handle evolution with inconsistency tolerance.

Keywords: Belief Revision, Argumentation, Dynamics of Arguments, Dynamics of Knowledge, Description Logics, Inconsistency Tolerance, Ontology Evolution.

1. Introduction

The promulgation of laws can be an interesting environment in which it is necessary to deal with reasoning and evolution of knowledge over inconsistent bases. This usually involves an extensive process in which laws, articles, and even evidence (according to court's jurisprudence) can enter in conflict with articles composing the new law. With a law promulgation the legal system is expected to evolve for incorporating the knowledge conforming the new law while ensuring it to be constitutional. To such end, it is necessary to identify a set of articles to be derogated, or amended, as part of the promulgation process. The investigations of this thesis work are developed with such motivation.

This thesis work develops theories for both reasoning about complex-structured knowledge over inconsistent knowledge bases (KBs) and for handling its evolution with inconsistency tolerance. The contributions are enclosed in three different areas within the artificial intelligence like *belief revision*, *argumentation*, and *ontology reasoning and evolution*. Regarding belief revision, the novel aspect is the proposal of change methodologies without consistency restoration. On the argumentation side, contributions are focused mainly on handling the dynamics of arguments in generalized argumentation frameworks (GenAFs). At a theoretical level, GenAFs are defined in an abstract manner, however, they are capable of being reified to different representation languages for handling specific knowledge according to a given KB. Finally, ontologies and in particular Description Logics (DLs), are studied in detail as a way to apply the proposed theories on some specific representation by handling complex-structured knowledge. This is relevant for handling conceptualization of norms in law sciences.

2. Contributions

The *Generalized (Abstract) Argumentation Framework* (GenAF) [3] formalizes a machinery for reasoning over inconsistent KBs disregarding any specific logic. Thus, the language used to represent knowledge and arguments remains unspecified at a theoretical level. In turn, a tuple $\pi = \langle \mathcal{L}, \mathcal{L}_{\mathtt{cl}}, \mathcal{L}_{\mathtt{pr}}, \mathcal{L}_{\mathtt{A}} \rangle$ identified as *argument language framework* (*AL-framework*), is given to provide some basic structure to the representation of knowledge and arguments built from it. $\mathcal{L}$ is the language of an underlying general logic (restricted to first-order logic, at most), $\mathcal{L}_{\mathtt{cl}} \subseteq \mathcal{L}$ is a language for claims, $\mathcal{L}_{\mathtt{pr}} \subseteq \mathcal{L}$ is a language for premises, and $\mathcal{L}_{\mathtt{A}} \subseteq \mathcal{L}_{\mathtt{cl}}$ is an assertional language (ground formu-

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lae). The set $\mathbb{A}$ will identify the domain of all possible AL-frameworks. Afterwards, given an AL-framework $\pi \in \mathbb{A}$, the *argument language* $\mathbb{A}_\pi$ will be referred for identifying the set $2^{\mathcal{L}_{\mathtt{pr}}} \times \mathcal{L}_{\mathtt{cl}}$ obtained from π, providing some structure to the notion of argument while keeping it abstract. In this sense, an argument in a GenAF ($\mathcal{B} \subseteq \mathbb{A}_\pi$) will be constructed as a (tree-like) linkage of *atoms* like $a \in \mathbb{A}_\pi$ which will stand for a single formula from the underlying KB. This allows to share the same primitive elements from both the framework (atoms) and the KB (formulae). A resulting advantage is that a GenAF may be straightforwardly adapted to deal with dynamics of knowledge as done in [6]: removing an argument from the framework would imply deleting a formula from the KB. Additionally, the specification of atoms as the inner components of arguments allows to establish the general form of formulae in order to identify the minimal portion of representable knowledge that could be removed from a KB. To this end, techniques of *knowledge compilation* are used as a way to put the KB into a normal form to specify a fine-grained form of knowledge. Some advantages of such decision are representing small arguments (and atoms), providing a fine-grained repairing methodology of formulae, and reducing the computational complexity of querying which offsets the additional costs of initial preprocessing for KB normalization. For DLs, works on knowledge compilation are proposed for transforming $\mathcal{ALC}$ ontologies according to some normal form in order to interpret $\mathcal{ALC}$ axioms straightforwardly as GenAF atoms. To this end, $\mathcal{L}$ is reified to $\mathcal{ALC}$, and the complete $\mathcal{ALC}$-AL-framework is specified after studying some DL's specific inconveniences such as negation of DL axioms, which is known to be a problem for some description languages.

Argument Theory Change (ATC) [6] applies notions from the classical theory of change, and particularly from the well known AGM model of change [1] to the field of abstract argumentation [2] by relying upon dialectical trees as the adopted argumentation semantics. An argument revision *à la* ATC revises an AF by an argument seeking for its warrant. To such end, the AF–and thus the set of arguments– is modified in order for the argumentation semantics to accept the new argument. We propose an approach to ATC under the name of *dialectic-global model* [5], that revises the KB (by analyzing the AF built from it), by an argument $\mathcal{R}$, which contains a minimal set of propositional rules inferring its claim α. The new revised KB determines a new AF whose argumentation semantics accepts α by rendering $\mathcal{R}$ undefeated from the dialectical tree rooted in it. This is achieved by identifying a set of arguments that should be removed from the AF to render $\mathcal{R}$ undefeated. However, the removal of arguments from the AF cannot be done straightforwardly, but as a consequence of the removal of beliefs from the underlying KB from where the AF is built.

By applying the dialectic-global model over GenAFs we tackle the problem of evolution with tolerancy to inconsistencies at a general level. Afterwards, we propose algorithms for implementing non-standard DL machineries for reasoning over inconsistent ontologies [4] by relying upon standard DL reasoners and their classic methodologies like *tableaux algorithms*.

3. Final Remarks

The complete thesis (in spanish) can be downloaded in http://cs.uns.edu.ar/~mom/publications/thesis.pdf. It was supervised by Marcelo A. Falappa and with the collaboration of Renata Wassermann, N. D. Rotstein, A. J. Garcia and G. R. Simari. The main contributions have been published in conferences and journals such as [3,4,5], among others. As a consequence of the thesis' related investigations two different lateral theories have been formed: ATC and DAF (Dynamic Argumentation Frameworks). Both theories generated additional publications in conferences and journals such as TPLP, AEPIA, AAAI, IJCAI, COMMA, and NMR, which additionally support the results of the thesis.

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