Embedding Defeasible Argumentation in the Semantic Web:
an ontology-based approach

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Abstract

The Semantic Web is a project intended to create a universal medium for information exchange by giving *semantics* to the content of documents on the Web by means of *ontology definitions*. Ontologies intended for knowledge representation in intelligent agents rely on common-sense reasoning formalizations. *Defeasible argumentation* has emerged as a successful approach to model common-sense reasoning. Recent research has linked argumentation with belief revision in order to model the dynamics of knowledge. This paper outlines an approach which combines ontologies, argumentation and belief revision by defining an ontology algebra. We suggest how different aspects of ontology integration can be defined in terms of defeasible argumentation and belief revision.

Keywords: Defeasible argumentation, Semantic web, Ontology algebra.

1   Introduction

Although the World Wide Web is a vast repository of information, its utility is restricted by limited facilities for searching and integrating different kinds of data, as search for queries is mostly *syntax-based* (*e.g.*, using keywords). The Semantic Web [2] has emerged as a project intended to create a universal medium for information exchange by giving *semantics* to the content of documents on the Web. A common way to provide semantics to documents on the web is through the use of *ontology definitions*. Common problems from common-sense reasoning (*e.g.*, reasoning with uncertainty or with incomplete and potentially inconsistent information) are present when defining ontologies. In recent years, defeasible argumentation has succeeded as approach to formalize such common-sense reasoning [6, 16]. In this preliminary report, we explore different alternatives for defining an ontology algebra whose semantics is based on defeasible argumentation and belief revision. We suggest how different aspects of ontology integration can be defined in terms of defeasible argumentation and belief revision.

2   Defeasible Logic Programming: Fundamentals

Defeasible Logic Programming (DeLP) [9] provides a language for knowledge representation and reasoning that uses *defeasible argumentation* [6, 16, 17] to decide between contradictory conclusions through a *dialectical analysis*. Codifying knowledge by means of a DeLP program provides

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a good trade-off between expressivity and implementability. Recent research has shown that DeLP provides a suitable framework for building real-world applications (*e.g.*, clustering algorithms [11], intelligent web search [4] and knowledge management [3]) that deal with incomplete and potentially contradictory information. In a defeasible logic program $\mathcal{P} = (\Pi, \Delta)$, a set Δ of defeasible rules $P \prec Q_1, \ldots, Q_n$, and a set Π of strict rules $P \leftarrow Q_1, \ldots, Q_n$ can be distinguished. An *argument* $\langle \mathcal{A}, H \rangle$ is a minimal non-contradictory set of ground defeasible clauses $\mathcal{A}$ of Δ that allows to derive a ground literal H possibly using ground rules of Π. Since arguments may be in conflict (concept captured in terms of a logical contradiction), an attack relationship between arguments can be defined. A criterion is usually defined to decide which argument of two conflicting arguments is preferred. In order to determine whether a given argument $\mathcal{A}$ is ultimately undefeated (or *warranted*), a dialectical process is recursively carried out. Given a DeLP program $\mathcal{P}$ and a query H, the final answer to H wrt $\mathcal{P}$ takes such dialectical analysis into account. The answer to a query can be either one of: *yes*, *no*, *undecided*, or *unknown*.

3 Belief Revision: Fundamentals

Belief Revision systems are logical frameworks for modelling the dynamics of knowledge. In dialogues between two agents, it is very common that an agent does not fully accept all the information provided by the other, but rather only parts of it. A *revision operator* is a function that maps sets of sentences K and A to a new set of sentences. In particular, in [8] the mecanism of a revision operator $K \circ A$ by a set of sentences with partial acceptance is defined as follows [8]: (1) the input set A is initially accepted, and (2) all posible inconsistencies of $K \cup A$ are removed. The mecanism of this operator is to add A to K and then eliminate from the result all possible inconsistency by means of an incision function that makes a "cut" over each minimally inconsistent subset of $K \cup A$ [8]. In Falappa *et. al.* work, beliefs are split into two distinguished sets: (1) *particular beliefs* K_P, that are represented by ground facts, and (2) *general beliefs* K_G, that will be represented by closed material implications. Thus, each belief base K has the form $K_P \cup K_G$ where $K_P \cap K_G = \emptyset$. When doing a kernel revision by a set of sentences, an incision function is needed to make a cut upon every set; *i.e.*, it necessary to determine which beliefs must be given up in the revision process. There are two possible policies: (1) discard particular beliefs, and (2) discard general beliefs. In the latter, at least one sentence should be discarded. Fallapa, Kern-Isberner and Simari [8] propose a refined characterization of revision by preserving retracted beliefs with a different status: retracted general beliefs will be preserved as *defeasible rules*. They also introduce a revision operator that generates defeasible conditionals from a revision operator upon belief bases represented in a first order language. It may be the case that in the revision process a conditional sentence of the form $(\forall(X))(\alpha(X) \rightarrow \beta(X))$ has to to be eliminated. This can occur because new incoming information results in an inconsistency. One of the following cases may occur: (1) there exists some individual satisfying α but not satisfying β, and (2) there exists some individual satisfying $\neg\beta$ but not satisfying $\neg\alpha$. Eliminating $(\forall(X))(\alpha(X) \rightarrow \beta(X))$ from the knowledge base would produce too much loss of information. As an alternative, in [8] the authors propose a transformation to change it into $\beta \prec \alpha$.

Definition 1 (Positive/negative transformation [8]) *Let $\delta = (\forall X_1 \ldots X_n)(\alpha \rightarrow \beta)$ be a material implication in $\mathcal{L}^+$. A positive transformation of δ, noted by $T^+(\delta)$, is a sentence of the form $\beta \prec \alpha$; a* negative *transformation of δ, noted by $T^-(\delta)$, is a sentence of the form $\neg\beta \prec \neg\alpha$.*

Definition 2 (Kernel (partial meet) composed revision [8]) *Let (K, Δ) be a knowledge structure, $(\circ)$ an operator of kernel (partial meet) revision by a set of sentences for K and A a set of sentences. The* kernel *(partial meet) composed revision of (K, Δ) wrt A is defined as: $(K, \Delta) \star A = (K', \Delta')$ such that $K' = K \circ A$*

- $create : d\text{-}Ontology$

- $addStrictRule : d\text{-}Ontology \times StrictRule \mapsto d\text{-}Ontology$

- $addDefeasibleRule : d\text{-}Ontology \times DefeasibleRule \mapsto d\text{-}Ontology$

- $conclusion : d\text{-}Ontology \times Fact \mapsto Answer$

- $translate : OWLOntology \mapsto d\text{-}Ontology$

- $isConsistent : OWLOntology \mapsto Bool$

- $areClassesCoherent : OWLOntology \mapsto Bool$

- $integrate : d\text{-}Ontology \times d\text{-}Ontology \mapsto d\text{-}Ontology$

- $redefine : d\text{-}Ontology \times d\text{-}Ontology \mapsto d\text{-}Ontology$

Figure 1: Possible signature for an algebra ontology using arguments

and $\Delta' = \Delta \cup \Delta'_1 \cup \Delta'_2$ where:

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\begin{array}{rcl}
\Delta'_1 & = & \{\alpha \prec true | \alpha \in (K_P \setminus K \circ A)\} \\
\Delta'_2 & = & \{T^+(\alpha) | \alpha \in (K_G \setminus K \circ A)\} \cup \{T^-(\alpha) | \alpha \in (K_G \setminus K \circ A)\}.
\end{array}
$$

The set K' contains the revised undefeasible beliefs, Δ'_1 is the transformation in defeasible rules of particular beliefs (also called *assumptions*) eliminated from K whereas Δ'_2 is the transformation of general beliefs eliminated from K into defeasible rules.

4   An Argument-Based Ontology Algebra for the Semantic Web

An *ontology* is a specification of a conceptualization. In computer science, ontologies establish a joint terminology between members of a community of interest. These members can be human or automated agents. In the context of the semantic web, an OWL ontology [15] is just a collection of information, generally information about classes and properties. In our approach, an ontology will be associated with a DeLP program representing knowledge, in which facts and strict rules are distinguished. More formally:

Definition 3 (*d-Ontology*) *A d-Ontology is a DeLP program $\mathcal{P} = (K_P \cup K_G, \Delta)$ where K_P stands for particular knowledge (facts about individuals), K_G stands for general knowledge (strict rules about relations holding among individuals), and Δ stands for defeasible knowledge (defeasible rules).*

Next we will discuss some elements involved in the formalization of an ontology algebra based on DeLP and Belief Revision. We present a possible signature for our algebra in Fig. 1. The specification of some of these operations is given in a functional programming-like style in Fig. 2.

Next we will briefly analyze some of the operations and their implementations. Operation $create$ allows to create an empty ontology (empty DeLP program). Operation $addDefeasibleRule$ allows to expand a given ontology by including a new defeasible rule (which can be easily modelled by set union). Operations $addStrictRule$ and $integrate$ are more complex to define, and are characterized in terms of a $\star$ operator. Part of our current research involves providing a suitable formalization of this operator. To do this, we are using results from belief revision theory as described in Section 3. The $conclusion$ operation allows to assign an epistemic status to literals.

Operation $translate$ is intended to link an XML-based OWL ontology [15] with a d-Ontology formalization. In the last years, the eXtended Markup Language (XML) has emerged as a standard for data interchange on the Web. XML allows authors to create their own markup. However, from

- $create = (\emptyset, \emptyset)$
- $addDefeasibleRule((\Pi, \Delta), R) = (\Pi, \Delta \cup \{R\})$
- $addStrictRule((\Pi, \Delta), R) = (\Pi, \Delta) \star \{R\}$
- $conclusion(Ont, H) = $ **call** DeLPEngineWarrantProcedure(Ont, H)
- $translate(OWLOnt) = $ **call** HunterAlgorithm$(OWLOnt)$
- $integrate((\Pi_1, \Delta_1), (\Pi_2, \Delta_2)) = (\Pi, \Delta)$, where: $(\Pi, \Delta') = (\Pi_1, \Delta_1) \star \Pi_2$, and, $\Delta = \Delta_1 \cup \Delta_2 \cup \Delta'$

Figure 2: Implementation for some of the operations of the ontology algebra

a computational perspective, user-defined tags carry as much semantics as standard HTML tags, as a computer does not simply know the relationships existing among them solely on the basis of their identifiers. Hunter proposed an algorithm that is capable of translating XML files into a set of first-order facts [12]. We think that this approach could be useful in our setting since it allows to encode an XML document as a set of facts in a d-Ontology.

5 Ongoing research. Conclusions

In this paper we have briefly outlined the main elements of a research line which integrates ontology theory, defeasible argumentation, and belief revision. A formalization of our proposal is underway on the basis of XML-based OWL syntax. In the literature, other authors claim that argumentation seems to be an appropriate tool for solving the problem of *ontology integration* [1]. Nevertheless, the results obtained so far seem still incipient.

Our research is also oriented towards consolidating such ontology integration. Results in this direction have been achieved by defining *interoperability* between ontologies. To reach interoperability two problems must be dealt with [18]: *structural heterogeneity* and *semantic heterogeneity*. Structural heterogeneity concerns the different representation of information as the information described by the same ontology can be represented in different ways. Semantic heterogeneity concerns the intended meaning of the described information; *e.g.*, information about persons can be described in different ontologies. Wiesman and Roos [18] proposes a domain independent method for handling interoperability problems by learning a mapping between ontologies. The learning method is based on exchanging instances of concepts that are defined in the ontologies. Although Wiesman and Roos' proposal is based on likelihood estimations, we think a similar approach could be used in the context of d-Ontologies on the basis of the *P-DeLP* argumentative framework, which extends DeLP knowledge representation capabilities by including vague knowledge and uncertainty [5, 7]. A more involved analysis for ontology integration might need other additional elements (such as resonance measures and similar criteria [13, 14]) that could be embedded into our d-ontologies to enrich their expressivity and representation capabilities.

Part of our current research is also involved with practical applications of defeasible argumentation for XML-based knowledge systems. In [10] we propose extending traditional web-based forms to incorporate defeasible attributes as part of the knowledge that can be encoded in a form. The proposed extension allows the specification of scripts for reasoning about form fields using a defeasible knowledge base, expressed in terms of a Defeasible Logic Program. We contend that defeasible argumentation provides a rich paradigm for modelling inference in the context of the Semantic Web initiative. As we have outlined in this paper, integrating argumentation with ontologies is a complex task which may lead to many promising contributions, such as enriching description of web resources in terms of defeasible rules, and providing a theory for merging ontologies with incomplete and po-

tentially inconsistent information. Research in these directions is currently being pursued.

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