A Modal Defeasible Reasoner of Deontic Logic for the Semantic Web

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ABSTRACT

Defeasible logic is a non-monotonic formalism that deals with incomplete and conflicting information, whereas modal logic deals with the concepts of necessity and possibility. These types of logics play a significant role in the emerging Semantic Web, which enriches the available Web information with meaning, leading to better cooperation between end-users and applications. Defeasible and modal logics, in general, and, particularly, deontic logic provide means for modeling agent communities, where each agent is characterized by its cognitive profile and normative system, as well as policies, which define privacy requirements, access permissions, and individual rights. Toward this direction, this article discusses the extension of DR-DEVICE, a Semantic Web-aware defeasible reasoner, with a mechanism for expressing modal logic operators, while testing the implementation via deontic logic operators, concerned with obligations, permissions, and related concepts. The motivation behind this work is to develop a practical defeasible reasoner for the Semantic Web that takes advantage of the expressive power offered by modal logics, accompanied by the flexibility to define diverse agent behaviours. A further incentive is to study the various motivational notions of deontic logic and discuss the cognitive state of agents, as well as the interactions among them.

Keywords: Agent Behaviour; Defeasible Logic, Deontic Logic, Modal Logic, Semantic Web

INTRODUCTION

Defeasible Logic, originally introduced by Nute (1994), is a non-monotonic formalism that deals with incomplete and conflicting information. Compared to other more mainstream non-monotonic approaches (Gottlob, 1992; Kautz & Selman, 1991; Soininen & Niemela, 1998), this approach offers enhanced representational capabilities and low computational complexity. Defeasible reasoning can represent facts, rules, priorities and conflicts among rules. Such conflicts usually emerge in the case of rules with exceptions, which are a natural representation for policies and business rules (e.g., Rissland DOI: 10.4018/jswis.2011010102
& Skalak, 1991; Schild & Herzog, 1993). In these cases priority information is often used in resolving conflicts among rules.

*Modal Logic* (Blackburn, de Rijke, & Venema, 2001), on the other hand, is a system of formal logic that deals with modalities, namely, expressions that are associated with the notions of *possibility* and *necessity*. However, modal logic is not restricted to these concepts, but can assume a variety of interpretations, depending on meaning, context and various other factors. Thus, according to the different interpretations, there exist diverse categories of modal logics, like *epistemic logic* that deals with the certainty of sentences (Meyer, 2001), *deontic logic*, which deals with the notions of obligation and permission (Hilpinen, 2001), *temporal logic*, which deals with temporal notions (Venema, 2001) and *doxastic logic* that deals with reasoning about beliefs (Meyer, 2003).

Modal logics are usually deployed as extensions to classical propositional logic with intentional operators. However, classical propositional logic requires complete, consistent and reliable information, requirements that are rarely met in real-life scenarios, which are by default defeasible in nature. Additionally, reasoning about motivational notions like beliefs, intentions or obligations, displays a significant degree of defeasibility. Consequently, instead of extending propositional logic, it is more appropriate to extend defeasible logic with modal logic elements and recent work confirms this trend (Governatori & Rotolo, 2004; Governatori, Hulstijn, Riveret, & Rotolo, 2007; Riveret, Rotolo, & Governatori, 2007).

The above types of logics are extremely suitable in the *Semantic Web*, which aims at enriching the available information on the Web with meaning, leading to better cooperation between end-users and applications (Berners-Lee, Hendler & Lassila, 2001). Defeasible and modal logics, in general, and deontic logic, in particular, can assist towards this direction, by providing means for modeling *multi-agent systems* (MAS), where each agent is characterized by its own cognitive profile and normative system, as well as *policies*, which define privacy requirements for a user, access permissions for a resource, individual rights, etc. Already, defeasible logic is applied in a number of related fields, like *semantic brokering* (Antoniou, Skylogiannis, Bikakis, & Bassiliades, 2007), *security policies* (Ashri, Payne, Marvin, Surridge, & Taylor, 2004), *e-contracting* (Governatori, 2005) and *agent negotiations* (Skylogiannis, Antoniou, Bassiliades, Governatori, & Bikakis, 2007) and, as the article argues, extending defeasible logic with deontic logic operators significantly improves our ability to model applications, naturally using concepts and notions similar to those we find in applications.

This article is based on previous work by the authors (Kontopoulos, Bassiliades, Governatori, & Antoniou, 2008) and reports on extending the *DR-DEVICE* first-order defeasible logic reasoner (Bassiliades, Antoniou, & Vlahavas, 2006) with reasoning capabilities on modal defeasible logic rule bases. Notice that in this work we focus mainly on deontic logic operators, without loss of generality, even if the techniques proposed can be applied to any modal logic. More specifically, the system has been extended to introduce rule modes that determine the modalities of the derived conclusions, as well as modalized literals that can serve as facts or premises of rule bodies. The aim is to develop a practical defeasible logic reasoner that will take advantage of the expressive power of modal logics, accompanied by the flexibility to define various agent types and behaviors. The motivation behind this work is two-fold, since we wish to: (a) study the various motivational notions, especially those of deontic logic, and (b) discuss the cognitive state of agents as well as the interactions among them, focusing mainly on deontic logic.

The rest of the article is organized as follows: The following section outlines the basics of defeasible logic, focusing mainly on its knowledge representation and inference mechanism, followed by a description of the fundamental notions of modal and deontic logics. The next section summarizes the core notions of extending defeasible logics with...
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