On Belief Change in Ontology Evolution

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We study the feasibility of applying the dominating paradigm of belief revision, the AGM theory, to logics outside its original scope, with special emphasis given on logics used for ontological representation in the Semantic Web. Such an application would allow determining whether a proposed change operator (e.g., an ontology evolution algorithm) behaves rationally or not. We give a number of interesting theoretical results related to the (generalized) AGM theory and show that our work can find important applications in dynamic environments employing non-classical logical formalisms. We focus on a particular such environment, namely ontology evolution in the Semantic Web, and show how our work can be used to provide ontology evolution researchers with powerful formal tools from the research area of belief revision.

Keywords: Belief Change, AGM Theory, AGM Postulates, Ontology Change, Ontology Evolution, Description Logics

1. Introduction

Updating knowledge is important for practically any knowledge base and knowledge representation formalism. The field of *belief change* (or *belief revision*) [3] deals with this problem, but most belief revision approaches focus on a particular class of logics (usually propositional logic); as a result, we now have a good understanding of the change processes for certain logics, but almost no idea of how these processes propagate to other logics.

Motivated by the idea that the driving intuitions behind change are independent of the peculiarities of the underlying logical formalism, we propose a generalization of the most important belief change theory, the AGM theory [1], to all monotonic logics. Our work gives several interesting theoretical results and allows the application of the AGM theory to handle changes in logics that are outside its original scope. We focus on one possible such application, namely the application of this work to ontologies in the Semantic Web. We perform a shallow, but broad literature review on the different fields dealing with changes on ontologies and argue that the field of *ontology evolution* [4] could, in many aspects, be viewed as a subfield of belief change. We provide the formal machinery allowing the migration of belief change tools and results to this field and show how ontology evolution research could benefit from such a migration. As a case study, we explore the feasibility of applying the generalized version of the AGM theory to the evolution of ontologies that use Description Logics (DLs) or OWL as their representation language.

2. Summary of Contributions

This work can be split into 4 different parts (contributions), briefly outlined in this section. The interested reader is referred to [2] for more details.

2.1. Ontology Change Terminology

One of the crucial tasks to be performed towards the realization of the vision of the Semantic Web is the encoding of human knowledge in special structures (ontologies), using formal representation languages. Simply creating an ontology is not enough though; knowledge needs to be updated as well. There are several reasons why knowledge in an ontology would need to change, such as changes in the world being modeled, design flaws or other problems with the original conceptualization, heterogeneity issues, changes in the user's needs or perspective and so on.

In all these cases, the ontological representation would need to be modified so as to form a more suitable conceptualization of the domain. We use the generic term *ontology change* to refer to the process of modifying an ontology in response to any given need. This generic term engulfs several different, but closely related research fields, including ontology evolution, alignment, merging, mapping and others. The first

contribution of this work is a shallow, yet broad review of recent work in those areas and the proposal of a certain terminology in a field plagued by the use of under-specified and confusing terms.

2.2. Belief Change and Ontology Evolution

The second part of this work focuses on ontology evolution, which refers to the process of modifying an ontology in response to a change in the domain or its conceptualization. We believe that the current research direction on ontology evolution leads to several problems, mostly related to the heavy dependency of the process on human participation and the lack of adequate formalizations. The key idea of our proposal towards resolving these deficiencies is the use of intuitions from the closely related field of belief change.

Towards this aim, we study the connections between the two fields and propose a formalization for ontology evolution that facilitates the migration of belief change techniques, tools and results. The solutions proposed in the belief change literature generally have all the properties missing from ontology evolution algorithms (automatic determination and implementation of changes, formal character and well-studied theoretical properties), so they could be of use in the ontology evolution field. This way, ontology evolution researchers will not have to "reinvent the wheel" for problems whose counterparts have already been studied in the belief change literature.

Our aim in this part of the work was not to describe any particular migration effort, but to provide some abstract ideas, as well as the necessary formal tools, upon which future research in this direction could be based.

2.3. Generalizing the AGM Theory

Following this abstract study, our research focused on the most influential belief change theory, namely the AGM theory. The aim of this part was to provide an exemplary application of the general research path we are proposing, as well as to show its feasibility.

Our study of the AGM theory was initiated by an attempt to generalize it so as to be applicable to all monotonic logics. The AGM theory, like most belief change approaches, focuses on classical logics, disallowing, among others, the main formalisms used in ontologies, like DLs and OWL. Our generalization showed that the AGM theory is actually applicable to a certain class of logics much larger than its original scope and uncovered some interesting theoretical properties, as well as connections with other formalisms like the foundational model and lattice theory.

2.4. DLs, OWL and the Generalized AGM Theory

In the fourth part of this work, our focus was narrowed so as to refer to the main ontology representation formalisms, namely DLs and OWL. We determined which members of these families of logics are compatible (or incompatible) with the generalized AGM theory and provided heuristics and results allowing one to determine the compatibility (or incompatibility) of logics not covered by this work. The main result of this part of our study is that certain DLs, as well as OWL, are not compatible with the AGM theory, while in other DLs the AGM theory can be successfully applied for the development of rational ontology evolution algorithms; for the latter category of DLs, an algorithm (operator) performing contraction that is compatible with the AGM model was defined.

3. Conclusion

Motivated by the idea that the notion of a rational change operation is independent of the underlying representation, we generalized the most popular belief revision theory, the AGM theory, so as to be applicable to a large class of monotonic logics. This allowed the development of several new results related to the AGM theory and uncovered some of its unknown facets. On the practical side, our work allows the application of the AGM theory to formalisms that were originally out of its scope and the formalization of the ontology evolution field using the secure foundations set by the mature belief revision field and the AGM theory.

References

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