Applying Belief Change to Ontology Evolution

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Abstract. Some of the key problems to resolve towards the realization of the vision of the Semantic Web include the creation, management and evolution of ontologies. This thesis focuses on the problem of ontology evolution. We believe that the ontology evolution community will benefit from the application of belief change techniques to ontologies and provide arguments in favor of this option. As an application of this viewpoint, we evaluate the feasibility of applying the AGM theory of contraction to the problem of ontology evolution, for ontologies represented using Description Logics (DLs) and OWL. Our approach raises interesting theoretical challenges and has an important practical impact too, given the central role that DLs and OWL play in the Semantic Web.

1 Introduction

One of the crucial tasks towards the realization of the vision of the Semantic Web is the efficient encoding of human knowledge in ontologies. The proper maintenance of these, usually large and complex, structures and, in particular, their adaptation to new knowledge (*ontology evolution*) is one of the most challenging problems in the current Semantic Web research.

There are several reasons that may force us to change an ontology. These include, but are not limited to, the need to improve the conceptualization of the domain, a shift in the users' needs or viewpoint, a dynamic change in the modeled domain, access to information previously unknown, classified or otherwise unavailable and so on.

2 Motivation

Current ontology evolution methods are based on varying levels of human intervention in order to perform properly. In particular, human participation is required in phases 2 and 3 of the ontology evolution process [8], namely the *Change Representation* and the *Semantics of Change* phase, during which the change(s) is (are) properly represented and the exact modifications required in the ontology in order to realize this (these) change(s) are determined.

We find the need for human intervention overly restrictive for real-world applications. The human user that intervenes in the process should be an ontology engineer and have certain knowledge on the domain. Very few people can be both domain and ontology experts. But even for these specialized experts, it is very hard to perform ontology evolution manually [8], because ontologies are large, complex structures with several and often unexpected interdependencies between their elements. Complex ontologies are developed by several ontology engineers; persons performing changes may be unaware of the full extent of their changes' effects, as they may not know all the parts of the ontology. In fact, no single ontology engineer may be in position to determine the full effects of a change. Finally, it is unrealistic to assume that an ontology engineer will always be nearby whenever an ontology needs to evolve; such an assumption overrules the use of ontologies in robots, agents and other automated systems. For all the above reasons, we think it is simply not practical to rely on humans for ontology evolution.

To develop fully automatic ontology evolution algorithms, several issues need to be addressed in a formal manner. For example, how can one track down all the alternative ways to address a given change, using a formal and exhaustive process? How can a computer system decide automatically on the "best" of the different alternatives? Most importantly, what is the definition of "best" in this context? Are there any properties that should be satisfied by a "good" ontology evolution algorithm? Unfortunately, resolving these issues in a general manner is not easy using the current research direction. Unless a more formal path is taken, ontology evolution research is doomed to never find answers to such questions.

2 Our General Proposal

In this thesis, we propose the use of *belief change* [7] techniques to address these issues. The problem of belief change is a very interesting and extensively studied problem which deals with the issue of deciding the changes to be performed upon a Knowledge Base (KB) in the face of new, possibly contradictory, information. We can view the problem of ontology evolution as a special case of the more general problem of belief change; this makes the problem of ontology evolution very similar, in several aspects, to belief change. Thus, building upon results from the rich belief change literature may help ontology evolution researchers to develop proper, automatic, rational and efficient evolution methods for ontologies.

This proposal can be viewed as a supplementary research direction, focusing on phases 2 and 3 of ontology evolution. It will allow the automatic determination of the proper modifications to be performed upon the ontology in response to a certain need for change, eliminating the need for human participation in these phases. Following this determination, the result could be fed to one of the current ontology evolution algorithms for final implementation. More details regarding this proposition, as well as a thorough discussion on the connections between belief change and ontology evolution can be found in [5].

3 A More Specific Proposal – Related Results

For the purposes of this thesis, this ambitious and abstract objective has been significantly reduced; more specifically, we studied the problem of determining the feasibility of applying the *AGM theory of contraction* [1] (the most influential theory of belief change) to ontologies based on DLs [2] and OWL [3], two families of languages which are expected to play a key role in the development of the Semantic Web.

The AGM theory set the foundations for future research in the field of belief change by introducing three different belief change operations, namely *expansion*, *revision* and *contraction*, as well as certain conditions, the so-called *AGM postulates*, which should be satisfied by any rational revision and contraction operator. The intuitions behind the development of the AGM postulates are independent of the actual language used to represent the knowledge. This supports our belief that several concepts used in belief change (in this case the concept of a "rational" operator) are transferable to the ontology evolution context. On the other hand, the exact formulation of the AGM postulates themselves uses certain assumptions made by AGM, which overrule several knowledge representation languages, including DLs and OWL.

This problem is typical of the problems encountered during the migration of belief change techniques to the ontology evolution context: the differences on the underlying intuitions are minimal, but the representation languages and formalisms used are quite different. In such cases, it makes sense to recast the theory under question (in this case the AGM theory) in a setting general enough to contain ontology representation languages (like DLs and OWL). For the purposes of this work, the operation of contraction was chosen because, according to AGM, it is the most fundamental among the three belief change operators [1] (even though revision is more often used in practice). Our research on revision is currently at a preliminary stage [6].

Our approach dropped most AGM assumptions and extended the definition of the contraction (and revision) operator; these generalizations were necessary to allow DLs and OWL (as well as several more representation languages) to be engulfed in our framework. Having set this general framework, the next step was to reformulate the AGM postulates of contraction in such a way as to be applicable to all logics in our more general framework, while preserving the original intuitions that led to each postulate's definition. The resulting postulates can be found in [4] and coincide with the original ones in the presence of the AGM assumptions.

Unfortunately, a major problem appeared soon after this reformulation: not all logics in our framework can admit a contraction operator that satisfies the (generalized) AGM postulates. Following this observation, our focus shifted on defining the conditions under which a logic admits a contraction operator satisfying all postulates; such logics were called *AGM-compliant logics*. Three different necessary and sufficient conditions for a logic to be AGM-compliant were formulated, based on the notions of *decomposability*, *cuts* and *max-cuts* (see [4] for details). As a side-effect, our work uncovered interesting connections of the AGM theory with lattice theory and provided a definite answer on the issue of the relation of the AGM theory with belief base algorithms and the foundational viewpoint [4].

Given the theoretical foundations set by this work, we were able to determine the applicability of the AGM theory to DLs and OWL. It was shown that if a DL allows a certain transformation to be defined, then it is AGM-compliant. This transformation is definable under very generic conditions and its existence depends on the operators, connectives and axioms allowed by the DL. Negative results were also presented, showing that certain DLs commonly used in ontologies, as well as OWL DL and OWL Lite, are not AGM-compliant. Finally, certain rules of thumb allowing one to determine the AGM-compliance of DLs not covered by this work, as well as some preliminary results related to revision were formulated. For more details, refer to [6].

4 Conclusion and Future Work

We believe that the study of belief change techniques under the prism of ontology evolution will lead to important breakthroughs in the field of ontology evolution. The significant work that has been performed during the last 20 years in the field of belief change will allow ontology evolution researchers to avoid re-inventing the wheel for problems whose counterparts have already been studied in the belief change literature.

The work performed in this thesis shows that this approach is generally feasible and may produce interesting results. However, our work was only restricted to one possible alternative of this more general research proposal, namely the connection of the AGM theory with ontology evolution. Therefore, this thesis has only scratched the surface of the problem, leaving several other alternatives unexplored.

Future work, in the context of this thesis, consists in developing an extension of this work to the operation of revision. We also plan to work on the issue of developing an AGM-compliant ontology evolution algorithm that could be used for integration in tools used for ontology evolution (existing or currently under development).

References

1. Alchourron, C., Gärdenfors, P., Makinson, D.: On the Logic of Theory Change: Partial Meet Contraction and Revision Functions. Journal of Symbolic Logic 50 (1985) 510-530
2. Baader, F., Calvanese, D., McGuinness, D., Nardi, D., Patel-Schneider, P. (eds.): The Description Logic Handbook: Theory, Implementation and Applications. Cambridge University Press (2002)
3. Dean, D., Schreiber, G., Bechhofer, S., Van Harmelen, F., Hendler, J., Horrocks, I., McGuiness, D., Patel-Schneider, P., Stein, L.A.: OWL Web Ontology Language Reference. W3C Recommendation (2004). Available at URL: http://www.w3.org/TR/owl-ref/
4. Flouris, G., Plexousakis, D., Antoniou, G.: Generalizing the AGM Postulates: Preliminary Results and Applications. In Proceedings of the 10th International Workshop on Non-Monotonic Reasoning (2004) 171-179
5. Flouris, G., Plexousakis, D. Handling Ontology Change: Survey and Proposal for a Future Research Direction. Technical Report, ICS-FORTH, TR-362 (2005)
6. Flouris, G., Plexousakis, D., Antoniou, G.: On Applying the AGM Theory to DLs and OWL. To appear in the Proceedings of the 4th International Semantic Web Conference (2005)
7. Gärdenfors, P.: Belief Revision: An Introduction. In Gärdenfors, P., (ed.) Belief Revision, Cambridge University Press (1992) 1-20
8. Stojanovic, L., Maedche, A., Motik, B., Stojanovic, N.: User-driven Ontology Evolution Management. In Proceedings of the 13th International Conference on Knowledge Engineering and Knowledge Management, vol. 2473, LNCS, Springer-Verlag, (2002) 285-300