Bridging Ontology Evolution and Belief Change

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Abstract. One of the crucial tasks towards the realization of the Semantic Web vision is the efficient encoding of human knowledge in ontologies. The proper maintenance of these, usually large, structures and, in particular, their adaptation to new knowledge (ontology evolution) is one of the most challenging problems in current Semantic Web research. In this paper, we uncover a certain gap in current ontology evolution approaches and propose a novel research path based on belief change. We present some ideas in this direction and argue that our approach introduces an interesting new dimension to the problem that is likely to find important applications in the future.

1 Introduction

Originally introduced by Aristotle, *ontologies* are often viewed as the key means through which the vision of the Semantic Web can be realized [1]. One of the most important ontology-related problems is how to modify an ontology in response to a certain change in the domain or its conceptualization (*ontology evolution*) [6].

There are several cases where ontology evolution is applicable [6]. An ontology, just like any structure holding information, may need to change simply because of a change in the domain of interest. In other cases, we may need to change the perspective under which the domain is viewed, incorporate additional functionality to the ontology according to a change in users' needs, or otherwise improve our conceptualization of the domain.

In this paper, we argue that the currently used ontology evolution model has several weaknesses and present an abstract proposition for a future research direction that will hopefully resolve such weaknesses, based on the related field of *belief change* [4]. Due to space limitations, only part of our proposition will be presented; the interested reader is referred to the full version of this paper for further details [2].

2 Ontology Evolution: Discussion on Current Research Direction

Ontology evolution tools have reached a high level of sophistication; the current state of the art can be found in [6]. While some of these tools are simple ontology editors, others provide more specialized features to the user, like the support for evolution strategies, collaborative edits, change propagation, transactional properties, intuitive graphical interfaces, undo/redo capabilities etc.

Despite these nice features, the field of ontology evolution is characterized by the lack of adequate formalizations for the various processes involved. Most of the available tools attempt to emulate human behavior, using certain heuristics which are heavily based on the expertise of their developers. They are not theoretically founded and their formal properties remain unspecified; moreover, they require varying levels of human intervention to work. In short, current work on ontology evolution resorts to ontology editors or other, more specialized tools whose aim is to *help* users perform the change(s) manually rather than performing the change(s) automatically.

We believe that it is not practical to rely on humans in domains where changes occur often, or where it is difficult, impossible or undesirable for ontology engineers to handle the change themselves (autonomous robots or agents, time-critical applications etc). This is true because manual ontology evolution is a difficult task, even for specialized experts. Human supervision should be highly welcome and encouraged whenever possible, but the system should be able to work decently even without it.

In current approaches, a change request is an explicit statement of the modification(s) to be performed upon the ontology; these are determined by the knowledge engineer in response to a more abstract need (e.g., an observation). Thus, current systems do not determine the actual changes to be made upon the ontology, but rely on the user to determine them and feed them to the system for implementation. This way, whenever the ontology engineer is faced with a new fact (observation), he decides on his alternatives and selects the best one for implementation by the system. This decision is based on his expertise on the subject, not on a formal, step-by-step, exhaustive method of evaluation. However, an automatic ontology evolution algorithm should be able to track down all the alternative ways to address a given change, as well as to decide on the best of these alternatives; the resolution of such issues requires a more formal approach to the problem of ontology evolution.

3 Belief Change and Ontology Evolution

Our key idea towards resolving these deficiencies is to exploit the extensive research that has been performed in the field of *belief change*. Belief change deals with the *adaptation of a Knowledge Base (KB) to new information* [4]. Viewing ontology evolution as a special case of the problem of belief change motivates us to apply results and ideas developed by the belief change community to ontology evolution.

We believe that our approach allows us to kill several birds with one stone. The mature field of belief change will provide the necessary formalizations that can be used by the yet immature ontology evolution field. Belief change has always dealt with the automatic adaptation of a KB to new knowledge, without human participation; the ideas and algorithms developed towards this aim will prove helpful in our effort to loosen up the dependency of the ontology evolution process on the knowledge engineer. Finally, previous work on belief change can protect us from potential pitfalls, prevent “reinventing the wheel” for problems whose counterparts have already been addressed in the rich belief change literature and serve as an inspiration for developing solutions to similar problems faced by ontology evolution researchers.

Unfortunately, a direct application of belief change theories to ontologies is generally not possible, because such theories focus on classical logic, using assumptions that fail for most ontology representation formalisms. Despite that, the intuitions behind such theories are usually independent of the underlying logic. In the sequel, we briefly revisit some of the most important concepts that have been considered in the belief change literature, in order to demonstrate the main tradeoffs and issues involved in their migration to the ontological context. Unfortunately, space limitations only allow a brief outline of these issues; for more details refer to [2].

- **Foundational and Coherence Models**: under the foundational model, there is a clear distinction between knowledge stored explicitly (which can be changed directly) and implicit knowledge (which cannot be changed, but is indirectly affected by changes in the explicit one). Under the coherence model, both explicit and implicit knowledge may be directly modified by the ontology evolution (or belief change) algorithm unambiguously. There are arguments in favor of both models in the belief change literature [5], which are also applicable in the ontological context.
- **Modifications and Facts**: the system could either be fed with the facts that initiated the change (observations, experiments, etc) or with the modifications that should be made in response to these facts. The former approach ("fact-centered") is commonly employed in belief change; the latter ("modification-centered") is more common in ontology evolution. We believe that the "fact-centered" approach is superior, because it adds an extra layer of abstraction, allowing the ontology engineer to deal with high-level facts only, leaving the low-level modifications that should be performed upon the ontology in response to these facts to be determined by the system. Moreover, this is the only approach that could lead to automatic determination of changes [2]. Finally, it allows the description of any type of change using 4 operations only (*revision*, *contraction*, *update*, *erasure* [2], [8]).
- **Primacy of New Information**: the common attitude towards the new information is that it should be accepted unconditionally. However, the distributed and chaotic nature of the Semantic Web implies that data in ontology evolution may originate from unreliable or untrustworthy sources. Thus, it might make sense to apply ideas from *non-prioritized belief change* [7], where the new information may be partially or totally rejected.
- **Consistency**: it is generally acknowledged that the result of an ontology evolution (and belief change) operation should be a consistent ontology (KB). Unfortunately though, in the ontological context, the term "consistent" has been used (others would say abused) to denote several different things. In the full version of this paper [2], we identify the different types of "consistency" that have appeared in the literature and determine those that are interesting in the ontology evolution context.
- **Principle of Minimal Change**: whenever a change is required, the resulting knowledge should be as "close" as possible to the original knowledge, being subject to minimal "loss of information". The terms "closeness" and "loss of information" have no single interpretation in the belief change literature, each different interpretation resulting to a different belief change algorithm. However, the considerations that have appeared in the belief change context can generally be migrated to the ontology evolution context. For more details on this issue, refer to [2].

The above considerations form only a partial list of the issues that have been discussed in the belief change literature. This analysis did not intend at providing specific solutions for the ontology evolution problem, but at showing that the choice of the change(s) to be made in response to some new information is a complex and multifaceted issue and that several considerations need to be taken into account before determining the proper modifications to be made; this is true for any type of knowledge change, including ontology evolution. Unfortunately, in the ontology evolution literature, most of these issues are dealt with implicitly, if at all, with no formal or informal justification of the various choices and without considering the different alternatives.

4 Conclusion and Future Work

We introduced an alternative approach to ontology evolution, based on a view of the problem as a special case of the more general and extensively studied problem of belief change [4]. This way, most of the techniques, ideas, algorithms and intuitions expressed in the belief change field can be migrated to the ontology evolution context. Our approach is described in detail in the full version of this paper [2].

We argued that this approach will lead to several formal results related to ontology evolution and resolve several weaknesses of the currently used model. Our study did not provide any concrete solutions to the problem; our goal was to provide the foundations upon which deeper results (like [3]) can be based, thus paving the road for the development of effective solutions to the ontology evolution problem.

This paper only scratched the surface of the relation between ontology evolution and belief change. Much more work needs to be done on this issue, both in theoretical and in practical grounds, by attempting the application of specific belief change algorithms, results or theories in the context of ontology evolution.

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