Artificial Intelligence 228 (2015) 195–216

Contents lists available at ScienceDirect

Artificial Intelligence

www.elsevier.com/locate/artint

Revision in networks of ontologies

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ARTICLE INFO

Article history:
Received 26 February 2014
Received in revised form 15 June 2015
Accepted 22 July 2015
Available online 28 July 2015

Keywords:
Network of ontologies
Alignment revision
Belief revision
Partial meet revision
Ontology alignment
Distributed system semantics

ABSTRACT

Networks of ontologies are made of a collection of logic theories, called ontologies, related by alignments. They arise naturally in distributed contexts in which theories are developed and maintained independently, such as the semantic web. In networks of ontologies, inconsistency can come from two different sources: local inconsistency in a particular ontology or alignment, and global inconsistency between them. Belief revision is well-defined for dealing with ontologies; we investigate how it can apply to networks of ontologies. We formulate revision postulates for alignments and networks of ontologies based on an abstraction of existing semantics of networks of ontologies. We show that revision operators cannot be simply based on local revision operators on both ontologies and alignments. We adapt the partial meet revision framework to networks of ontologies and show that it indeed satisfies the revision postulates. Finally, we consider strategies based on network characteristics for designing concrete revision operators.

1. Introduction

Knowledge may be organised in a distributed way in which independent theories are related by correspondences between theory features (formulas, predicates). Relations between different theories may have different nature: refinement, competing theories, complementary theories, etc. We call a set of theories related by such relations a network of ontologies. The notion of networks of ontologies relies on minimal assumptions regarding ontologies and alignments: their semantics must define a consequence relation which is a closure relation. Alignments independently express constraints on acceptable models of ontologies.

One motivation and inspiration for this work is the management of networks of ontologies in the semantic web. The semantic web relies on knowledge deployed and connected over the web. This knowledge is based on ontologies expressed in logical languages, such as RDF, RDF Schema and OWL [27,2]. Because of the multiplicity of ontologies, they may be connected through alignments expressing correspondences between their concepts. This allows for translating assertions across ontologies or merging them.

Problems arise when a modification in an ontology or an alignment leads to inconsistency. For instance, it happens everyday that new objects occur and are reported, such as a particular building in a given city. Such a building may belong to a category in an ontology for civil engineering, for instance, glass-walled building. Glass-walled buildings in this ontology may be considered by a particular ontology alignment as subsumed by energy-inefficient buildings in an energy saving ontology. But because this building is engineered with particular active components, it is in fact assigned to the energy-efficient buildings in that same ontology. However, energy-efficient and energy-inefficient buildings are considered exclusive. Hence, this small network of (two) ontologies may be interpreted as inconsistent, because the same building belongs to two disjoint

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http://dx.doi.org/10.1016/j.artint.2015.07.007
0004-3702/

classes. Something has to be done for restoring consistency and still accommodating this new building. It may consist of modifying the ontologies (the two classes are not exclusive), the data (this building is not to be considered as a glass-walled building) or the alignment (not all glass-walled buildings are energy-inefficient).

Belief and knowledge revision have been introduced for dealing with such problems in logical theories. They provide operators to modify a theory in a way which is consistent and as minimal as possible.

This work investigates the design of belief revision operators for networks of ontologies and considers the problems specific to this broader context. There may be several ways to achieve this:

- Combine local revision operators to achieve global revision. We show that, already for the reasonable case of partial meet revision, this is not a viable strategy.
- Consider a network of ontologies as a single "regular" theory to which classical belief revision is applied. Although this is in theory possible, this does not preserve the structure of the network of ontologies.

Instead, we show how belief revision operators, constrained by the structure of networks of ontologies, may be defined. This preserves the opportunity to ground operators on the structure of these networks. Moreover, this does not require encoding the problem in a classical revision problem, and decoding it into a revised network of ontologies.

From the standpoint of belief revision, we thus introduce a novel way to consider several independently managed theories (loosely) related by constraints which helps exploiting them together.

In particular, we consider what are revision operators in a network of ontologies, how to define postulates governing the behaviour of such operators and how to design them. We raise issues specific to networked ontologies and show how differences between ontologies and alignments can be used for designing specific operators. Although we go as far as providing concrete revision operators, this work primarily aims at highlighting the principles and issues of applying revision to networks of ontologies.

For dealing with this problem, we first introduce networks of ontologies and alignments through their syntax and semantics (Section 2) and recall the principles of knowledge revision and update (Section 3). We then introduce two revision operators, based on alignments and ontologies, as well as associated consequences and two notions of consistency (Section 4). We provide revision postulates for these operators mirroring the basic Alchourrón–Gärdenfors–Makinson (AGM) postulates and show that such operators generalise local operators (Section 5). We discuss the use of these local operators for defining global operators and provide definitions of partial meet revision for networks of ontologies (Section 6). Finally, we provide several minimality criteria specific to networks of ontologies (Section 7). Relation to other work is discussed (Section 8) before concluding.

2. Networks of ontologies

We first precisely define what alignments and networks of ontologies are through their syntax (Section 2.1) before addressing their semantics (Section 2.2). There is no "standard" semantics for networks of ontologies, so we provide here an abstract view that aims at covering those which have been proposed so far. Based on this framework, we define the notions of closure from this semantics (Section 2.3) and we set constraints that must be satisfied by such a semantics to support the results of this paper (Section 2.4).

We consider ontologies as logical theories. The semantics of an ontology o is only considered in this paper through its set of models ($\mathcal{M}(o)$) and its induced consequence relation ($\models$). Such a relation satisfies three properties (o, o' are ontologies, i.e., sets of assertions, δ and γ are assertions):

extensivity $\{\delta\} \models \delta$
monotony if $o \models \delta$ then $o \cup o' \models \delta$
idempotency if $o \models \delta$ and $o \cup \{\delta\} \models \gamma$ then $o \models \gamma$

We assume a consequence closure function $Cn^{\omega}(o) = \{\delta \mid o \models \delta\}$.

Although the word ontology is used here and examples are given with respect to a minimal ontology language. Results in this paper rely only on the consequence relation induced by model theory. They apply to many types of logical theories. In particular, the remainder will use classical revision operators in ontologies.

2.1. Alignments and networks of ontologies

Alignments express the correspondences between entities of different ontologies [17]. Given an ontology o in a language L, we use an *entity language* ($Q_L(o)$) for characterising those entities that will be put in correspondence. The entity language can be simply made of all the terms or formulas of the ontology language based on the ontology vocabulary. It can restrict them to the named terms or, on the contrary, extend them to all the queries that may be expressed on this vocabulary. Alignments express relations between such entities through a finite set Θ of relations which are independent from ontology relations.