Requirements for Representing Situations

Hoekstra, R.; Liem, J.; Bredeweg, B.; Breuker, J.

Publication date
2006

Document Version
Final published version

Published in
OWLED '06 : OWL: Experiences and Directions 2006

Requirements for Representing Situations*

Rinke Hoekstra[2], Jochem Liem[1], Bert Bredeweg[1], and Joost Breuker[1,2]

[1] Human Computer Studies Laboratory, Informatics Institute, Faculty of Science, University of Amsterdam, The Netherlands,
{jliem,bredeweg,breuker}@science.uva.nl
[2] Leibniz Center for Law, Faculty of Law, University of Amsterdam, The Netherlands, hoekstra@uva.nl

Abstract. This paper describes experiences with the limitations imposed by OWL on the representation of common constructs in two distinct application domains: qualitative reasoning models in ecology, and ontology based legal reasoning. We will show that OWL is not expressive enough to unambiguously represent situations using restrictions. Secondly, we show that representing the idea that instances in different concrete situations are actually the same individual, is a non-trivial issue which cannot be adequately solved in OWL. Thirdly, a representation of a general situation cannot be easily reused within other situations.

1 Introduction

This document describes the limitations imposed by OWL on the representation of common constructs in two typical AI applications: qualitative reasoning [2], and ontology based legal reasoning [1]. The common denominator of these two applications is that they both involve reasoning about situations and their interrelations. Situations are frameworks that describe configurations, e.g. the arrangement of furniture in an office. The qualitative reasoning and modelling (QRM) workbench Garp3[3] allows users to export and import models and scenarios expressed in OWL. For this purpose, an ontology was developed that captures the definition of QRM ingredients and their usage restrictions. Exported models are stored in an online repository, allowing users to share and search for reusable model fragments. Ontology based responsibility attribution in DIRECT [1] identifies causal and intentional relations between events in a commonsense story. This identification is done by matching a perceived difference between two situations to processes in an ontology.

2 Ambiguity of Situation Descriptions

Both applications use classification to determine whether a concrete situation is an instance of a known situation. It is therefore essential to correctly represent

* This work is co-funded by the EC within the 6^{th} Framework Programme (2002-2006), project NaturNet-Redime (http://www.naturnet.org), no. 004074.

[3] http://www.garp3.org

such generic situations. A concrete situation is described as an instance with relations to other instances, i.e. the elements of that situation. Generic situations are classes, defined by necessary and sufficient conditions. Unfortunately, OWL is rather weak at capturing functional concepts that describe the configurations or patterns of concepts in situations, i.e. concepts that describe connections, such as chains, dependencies etc. Both OWL-DL[4] and OWL 1.1[5] do not allow for precise enough descriptions of classes, and leave room for ambiguity.

Consider an example situation where 3 distinct populations prey on each other: a population P_x consumes a population P_y, which in turn consumes P_z:

```
class ThreePopulationsPreyingOnEachOther consistsOf exactly 3 Population
                                         consistsOf some (Population and
                                                    (consumes some (Population and
                                                    (consumes some Population))))
```

This definition has multiple interpretations, and subsumes situations consisting of three populations where population P_x preys on P_y, and P_y preys on P_z, or where P_x preys on P_y, and P_y preys on P_x, or even a situation where P_x preys on itself. Furthermore, it does not require the two consumed populations in the second consistsOf restriction to overlap with the three populations required by the cardinality restriction.

Without some means to distinguish between instances, it is impossible to unambiguously represent general situations which contain multiple instances of the same type. The OWL 1.1 draft specification introduces anti-symmetrical and irreflexive properties. Although these solve part of the issue, altering the type of a property for a single generic situation can prevent its use in the definition of other situations (which would become inconsistent). Furthermore, it provides no solution in cases where the restrictions range over multiple different properties (see Section 3). Intuitively, it is preferable to define these restrictions at class, and not by tweaking the definition of a property: e.g. the pattern by which consumption takes place does not necessarily define the meaning of the relation.

3 Maintaining Identity of Individuals

In the previous section we discussed some of the limitations of OWL when representing generic situations, in this section we focus on problems with concepts that range across situations. Concepts that capture *change* such as tasks, workflow, processes, causation and version management require some notion of identity to keep track of the differences between instances that represent the same entity. Note that we require the OWL reasoner to recognise change, not *apply* it. Consider the definition of a Transition between two situations:

[4] `http://www.w3.org/TR/owl-ref/`

[5] `http://www-db.research.bell-labs.com/user/pfps/owl/overview.html`

class Standstill-to-Moving Transition and
from some (Physical-Object and (acceleration has zero)) and
to some (Physical-Object and (acceleration has plus))

This definition adds a dimension to the limitations we discussed in section 2 since we cannot express that the individuals addressed by the pre and post-condition should share the same identity.[6] The notion of individual in OWL stands for both individual and *instance*: the terms are used indiscriminately. Conceptually, individuals have an identity and a life-cycle, while instances are occurrences of individuals at a particular time and a particular place, i.e. they are situation dependent.

Although OWL Individuals can be said to be the same or different, these relations cannot be used to express an identity relation between two different instances of the same individual as they can have different property values. At the instance level, other ways exist to express identity relations between OWL individuals: 1) introduce a transitive symmetric property such as sameIdentityAs to relate between OWL individuals that share some identity, 2) assert membership of a particular class for each identity, or 3) relate instances to an OWL individual that represents the shared identity.

These solutions are problematic in class definitions that range over multiple instances of shared identity. The definition will be either too generic, or too specific. Because OWL does not allow the description of relations between classes used in different restrictions, maintaining a sameIdentityAs property relation over the pre- and post condition of a transition is not possible. This means that the existence of the sameIdentityAs relation cannot be used as a condition for classification. The use of a shared ancestor class or OWL individual to maintain identity, as e.g. in the definition of transitions, requires an explicit reference to the identity being maintained: transitions lose generality and become identity-specific.

4 Composition and Reuse of Situation Descriptions

The ability to share and reuse knowledge components is one of the pillars of the ontology engineering field. In QR, general situation descriptions are often reused to describe more complex situations. Although OWL DL allows for simple scenarios for reuse, complex situation inclusion is currently impossible.

A straightforward example of reuse is a situation which is equivalent to the intersection of two other situations. However, we cannot express relations between the elements of the situations as there is no way to refer to the contents of the two situations. Furthermore, if we reuse by subsumption, we cannot impose cardinality restrictions on the situations we reuse, e.g. a general situation which is the combination of multiple situations of the same type is impossible to express.

[6] OWL 1.1 supports disjoint properties, which allows us to state that the objects should at least be owl:differentFrom each other

An alternative is the use of explicit import statements. The proposed OWL 1.1 specification introduces complex role inclusion axioms, which allow us to express that the composition of import with consistsOf holds as a subproperty of consistsOf: $\mathsf{imports} \circ \mathsf{consistsOf} \sqsubseteq \mathsf{consistsOf}$. Using this added expressiveness we can represent the reuse of model fragments in other fragments, and situation inclusion in general. However, for classification to work, concrete situations need to reflect the structure of imports in generic situations: an undesirable solution.

5 Conclusions and Discussion

This paper presented the problems encountered when expressing QR models and ontologies for legal reasoning using OWL. Firstly, we have shown that OWL is not expressive enough to unambiguously represent general situations using restrictions. Secondly, we have shown that representing the idea that instances in different situations are actually the same individual, is a non-trivial issue which cannot be adequately represented in OWL. And thirdly, general situations represented using restrictions cannot be easily reused within other situation descriptions.

The first two issues suffer essentially from the same limitations. Even with the added expressiveness of OWL 1.1 it remains impossible to properly distinguish between individuals in class restrictions. Ideally OWL would support the use of variables in restrictions; variables can be local to classes. A candidate for lifting this limitation is the Semantic Web Rule Language (SWRL)[7]. Rules can help because they introduce variables, and enable us to infer extra information about the relations between the instances in a situation. However, because rules can only *assert* new knowledge, they cannot aid in posing extra restrictions for classification: they cannot *prevent* classification. Furthermore, maintaining consistency between inferences of the classifier and the results of rules firing is not trivial.

In its current form, OWL has limited use as a knowledge representation language for AI applications. The OWL 1.1 proposal seems to be a significant improvement, but is still too weak to express identity constraints. This means that correspondence between the semantics of ontologies and models expressed in OWL and their internal interpretation in knowledge based systems – at least those we discussed here – cannot be guaranteed.

References

[1] Rinke Hoekstra and Joost Breuker. Commonsense causal explanation in a legal domain. *Artificial Intelligence & Law*, 2006. Special Issue on Legal Ontologies and Artificial Intelligence Techniques. (Accepted).

[2] Jochem Liem and Bert Bredeweg. OWL and qualitatative reasoning models. In *29th annual German Conference on Artificial Intelligence (KI2006)*, Lecture Notes on Artificial Intelligence. Springer, 2006. (In press).

[7] `http://www.w3.org/Submission/SWRL/`