Semantics of the distributed ontology language: Institutes and Institutions

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OWL is a popular language for ontologies. Yet, the restriction to a decidable description logic often hinders ontology designers from expressing knowledge that cannot (or can only in quite complicated ways) be expressed in a description logic. A practice to deal with this problem is to intersperse OWL ontologies with first-order axioms, e.g. in the case of bio-ontologies where mereological relations such as parthood are of great importance, though not definable in OWL. However, these remain informal annotations to inform the human designer, rather than first-class citizens of the ontology with formal semantics and impact on reasoning.

A variety of languages is used for formalising ontologies.[4] Some of these, as RDF, OBO and UML, can be seen more or less as fragments and notational variants of OWL, while others, like F-logic and Common Logic (CL), clearly go beyond the expressiveness of OWL.

This situation has motivated the distributed ontology language (DOL), a language currently under active development within the ISO standard 17347 Ontology Integration and Interoperability (OntoIOp). In DOL, heterogeneous and distributed ontologies can be expressed. At the heart of this approach is a graph of ontology languages and translations [9]. This graph will enable users to

- relate ontologies that are written in different formalisms (e.g. prove that the OWL version of the foundational ontology DOLCE is logically entailed by the first-order version);
- re-use ontology modules even if they have been formulated in a different formalism;
- re-use ontology tools like theorem provers and module extractors along translations between formalisms.

In this contribution, we will present the syntax and semantics of DOL. DOL shares many features with the language HetCASL [8] which underlies the Heterogeneous Tool Set Hets [10]. However, it also adds a number of new features:

- ontology module extraction: give me a subtheory that contains all relevant logical information w.r.t. some subsignature;
- projections of theories to a sublogic;
- ontology alignments, which involve partial or even relational variants of signature morphisms;
- combination of theories via colimits;
- referencing of all items by URLs, or, more general, IRIs.

What is the semantics of DOL? Previous presentations of the semantics of heterogeneous logical theories [13, 4, 11, 7, 9] relied heavily on the theory of institutions [6]. The central insight of

[4] For the purpose of this paper, "ontology" can be equated with "logical theory".

the theory of institutions is that logical notions such as model, sentence, satisfaction and derivability should be indexed over signatures (vocabularies). In order to abstract from any specific form of signature, category theory is used.

However, the use of category theory diminishes the set of potential readers. Moreover, there is a line of *signature-free* thinking in logic and ontology research; for example, Common Logic [3] names its signature-free approach a chief novel feature. Likewise, many abstract studies of consequence and satisfaction systems [5, 12, 1, 2] disregard signatures. Hence, we base our semantics on the newly introduced notion of *institutes*. These start with the signature-free approach, and then introduce signatures a posteriori, assuming that they form a preorder. While this approach covers only signature inclusions, not renamings, it is much simpler than the category-based approach of institutions. Of course, for features like colimits, full institution theory is needed. We therefore show that institutes and institutions can be integrated smoothly.

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