On Relating Heterogeneous Elements from Different Ontologies

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Abstract. In the extensive usage of ontologies envisaged by the Semantic Web there is a compelling need for expressing mappings between different elements of heterogeneous ontologies. State of the art languages for ontology mapping enable to express semantic relations between homogeneous components of different ontologies; namely, they allow to map concepts into concepts, individuals into individuals, and properties into properties. In many real world cases this is not enough; for example when relations in an ontology correspond to a class in another ontology (i.e. reification of relations). To support this kind of interoperability we need therefore richer mapping languages, offering constructs for the representation of heterogeneous mappings. In this paper, we propose an extension of Distributed Description Logics (DDL) with mappings between concepts and relations. We provide a semantics of the proposed extension and sound and complete characterisation of the effects of these mappings in terms of the new ontological knowledge they entail.

1 Introduction

Most of the formalisms for distributed ontology integration based on the p2p architecture provide a language (hereafter called mapping language) able to express semantic relations between concepts belonging to different ontologies. These formalisms can express that a concept C in Ontology 1 is equivalent (less general than, more general than) a concept D in Ontology 2 (see [15] for a survey). Few mapping languages allow also to express semantic relations between properties in different ontologies [9][10][11], and thus state that a relation R in Ontology 1 is equivalent (less general than, more general than) a relation S in Ontology 2. These type of mappings are able to cope a large, but not the totality of the heterogeneity between ontologies.

Assume, for instance, that a knowledge engineer builds an ontology of family unions containing the binary relations marriedWith and partnerOf between two persons. Suppose also that a second ontology engineer, asked to design an ontology for the same purpose, declares a concept Marriage, whose instances are the actual civil or religious marriages and the concept civilUnion, whose instances are all the civil unions. We can easily see that while the first ontology prefers to model unions as relations, the second represents them as concepts.
Despite this difference of style in modelling, the concept *Marriage* and the relation *marriedWith* represent the same (or a very similar) real world aspect, and similarly with *partnerOf* and *civilUnion*. For instance, we can expect that for all married couples in the first ontology, there is a corresponding marriage element in the second ontology, and similarly for the civil unions. To reconcile the semantic difference between the two heterogeneous representations we need a mapping language that allows to map concept of one ontology to relations of another ontology.

Motivated by these observations, Ghidini and Serafini have illustrated in [11] the need of expressive mapping languages that must incorporate not only *homogeneous mappings*, that is mappings between concepts and mappings between relations of different ontologies, but also *heterogeneous mappings*, that is mappings between concepts and relations in the sense illustrated above. They present a preliminary investigation on how to define such expressive mapping language in the framework of Distributed Description Logics (DDL) [14], a refinement of the multi-context logic presented in [8,9] to the DL-based framework for the formal representation of ontology, but they do not go beyond preliminary statements and definitions, especially in the case of heterogeneous mappings. In [10] the authors take a step forward and present a proposal and an algorithm for the representation and reasoning with *homogeneous mappings*. In this paper we continue this stream of work by addressing the more complex task of representing and reasoning with *heterogeneous mappings* (as well as *homogeneous mappings*) which represent a specific relation between heterogeneous ontologies, namely the correspondence between a concept and a relation. Thus the goals of this paper are: (i) to extend the framework of DDL, introducing mechanisms for the representation of heterogeneous mappings between different ontologies, (ii) to define a clear semantics for the proposed mapping language, and (iii) to investigate the logical properties of the proposed mapping language.

# 2 A Rich Language for Mappings

Description Logic (DL) has been advocated as the suitable formal tool to represent and reason about ontologies. Distributed Description Logic (DDL) [14] is a natural generalisation of the DL framework designed to formalise multiple ontologies pairwise linked by semantic mappings. In DDL, ontologies correspond to description logic theories (T-boxes), while semantic mappings correspond to collections of *bridge rules* (B).

In the following we recall the basic definitions of DDL as defined in [14,11], and we provide a new semantics for heterogeneous mappings.

## 2.1 Distributed Description Logics: The Syntax

Given a non empty set $I$ of indexes, used to identify ontologies, let $\{DL_i\}_{i \in I}$ be a collection of description logic [1]. For each $i \in I$ let us denote a T-box of

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1 We assume familiarity with Description Logic and related reasoning systems, described in [1].