Provenance, Trust, Explanations – and all that other Meta Knowledge

Renata Dividino, Simon Schenk, Sergej Sizov, Steffen Staab

Meta knowledge, i.e. knowledge about knowledge, is important in oder to judge the validity or appropriateness of the knowledge. We present a generic framework for managing and querying meta knowledge considering the most widespread paradigms for knowledge representation, i.e. RDF, Logic Programming, and Description Logics.

1 Introduction

One of the key benefits of the Semantic Web technology is the better support of decentralized, self-organizing knowledge exchange between users. When integrating knowledge from different sources or even from the full range of the Semantic Web, we are faced with highly varying quality of information. Hence, one of the major challenges is to investigate the value of information based on the trustworthiness of its sources, the time of validity, the certainty, or the vagueness asserted to explicitly specified or derived facts. In fact, this list of different types of 'knowledge about knowledge' (i.e. meta knowledge) is not even complete, one may be interested in the creator(s) of a fact, the document(s) in which it is stated — maybe implicitly, the web sites that certified it, and maybe many more dimensions. It becomes evident from such an enumeration that different types of meta knowledge should become accessible by a *generic framework* and not only by custom approaches that consider one particular dimension of meta knowledge at a time, possibly with incompatible assumptions.

It is the contribution of this paper to develop such a coherent framework by illustration with and reference to more specialized papers in the area of management of meta knowledge (in particular [1, 4, 10, 11]). To illustrate our framework let us first discuss a short example. Our sample application aims to suggest the local chair(s) for a multimedia congress in Koblenz, Rhineland-Palatinate. We may assume that the search for suitable candidates with relevant research profiles and appropriate location exploits collected knowledge from Semantic Web pages of multiple Computer Science departments.

Table 1 shows the instantiation for our sample scenario using a simplified abstract syntax for representing relevant facts and associated meta knowledge. We assume that all facts and axioms have been obtained from academic sites (University of Koblenz, FU Berlin, and Fraunhofer institutes) and some of them are also associated with last-modified timestamps (in the range between 2002 and 2008) which reflect the recency of knowledge. The collection presented in our example contains information about affiliation and research interests of academic scientists (e.g. the fact $\#_1$ represents the statement 'Research topic of Stefan Mueller is Computer Graphics'), as well as some definitions for the domain terminology (e.g. statement $\#_6$ defines a scientist to be a researcher working at the university) and rules for suggesting candidate chairs (e.g. statements $\#_8$ defines that 'Stefan Mueller is affiliated with only the University of Koblenz' and $\#_9$ postulates that the successful candidate should work in Rhineland-Palatinate). The reader may note that the facts shown in Table 1 may require in practice the use of representation formalisms with different expressivity and complexity. While the facts $\#_1..\#_5$ can be expressed in RDF, the remainder requires more expressive frameworks like Logic Programming (for facts $\#_9, \#_{10}$) or OWL (for facts $\#_6..\#_8$).

An evident problem with the presented collection is that particular facts about affiliations and research interests (facts $\#_1..\#_5$) refer to *different* scientists, named likewise professor Stefan Mueller. The first one is a professor for Computer Graphics from the University of Koblenz, the second one is a professor for German Grammar of the University of Berlin. For this reason, some conclusions of our mix-up knowledge base may appear strange and curious. From the user's perspective, several sceptical questions may arise:

1. What are the research topic(s) of Stefan Mueller? Who said this (and when)?
2. May I trust the assessment that Stefan Mueller is a scientist?
3. What is the explanation that Stefan Mueller is the recommended candidate?

This paper points out the commonalities and differences between approaches that can be used to compute the solutions to these questions using meta knowledge. We consider three of the most widespread paradigms for knowledge representation, i.e. an algebraic approach, logic programming, and description logics. The differences result, first, from the different algebraic and logical mechanisms used for querying and inferencing upon a knowledge base. Second, the differences result from the algebraic or logic approaches used to formalize a theory for meta knowledge. The commonalities are found in the way in which we treat meta knowledge results computation. We represent meta knowledge by annotations of statements/axioms and combine such annotations in a versatile manner.

The design space of our treatment for meta knowledge is depicted in Figure 1. In the following, we instantiate in Section 2 the use of meta knowledge for algebraic querying methods (using our system Meta-K), in Section 3 for Logic Programming approaches (using the logic programming system Ontobroker [3]), and in Section 4 for OWL knowledge bases (using our system OWLMeta-K). The figure also indicates which combinations of knowledge and meta knowledge theories constitute straightforward extensions (using a '+') due to the decrease of the expressiveness power of the

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