CROSS DOMAIN KNOWLEDGE VERIFICATION
Verifying Knowledge In Foundation Ontology Based Domain Ontologies

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Abstract: Knowledge verification refers to the process of making sure that the knowledge shared between knowledge bases of two parties is correctly understood on both sides. Domain ontologies developed out of a foundation ontology have a potential to improve the knowledge verification methods. This can be done by following concepts in domain ontologies to their origin and constituent conceptualisations in the foundation ontology. This is possible when matching ontologies belonging to two different domains but developed out of a single foundation ontology. Along with the concepts, a prescribed way of using these concepts by domain ontology builders also needs to be included in the foundation ontology. This prescribed way can exist in the form of an ontology of constraints which governs and shapes the building of domain ontologies according to the needs of the verification system and thus makes them more interoperable.

1 INTRODUCTION

Knowledge verification systems are needed to ensure the correct understanding of concepts and related knowledge among parties involved in the knowledge sharing activity. This paper proposes a way of verifying the authenticity of knowledge and concepts across different domain ontologies developed out of a single foundation ontology. It first gives a brief review of the literature on existing domain ontologies and ontology matching tools, a discussion about the proposed ontology matching methodology follows and conclusion and future work is presented in the end.

2 EXISTING RESEARCH

2.1 Foundation and Domain Ontologies

To make knowledge bases more shareable and expandable, instead of building them from scratch, it is more apt to develop them out of a single agreed upon foundation or standard (Neches et al, 1991). Foundation ontologies provide the basis for this standard. They make the expansion and integration of knowledge bases easier. This is because if two system builders build their knowledge bases on a common ontology, the system will share a common structure, and it will be easier to merge and share the knowledge bases (Swartout et al, 1997).

Some of the existing foundation ontologies include Standard Upper Ontology – SUO (Niles & Pease, 2001), Suggested Upper Merged Ontology – SUMO (Niles & Pease, 2001), DOLCE (Gangemi et al, 2002), WordNet (Deng et al, 2009), and Cyc Ontology (Matuszek et al, 2006).

Foundation ontologies like these may help in reducing semantic heterogeneity by restricting domain ontology builders to match their own conceptualisations against a common foundation, so that all communication is done according to the constraints derived from the ontology (Schorlemmer & Kalfoglou, 2005). Domain ontologies on the other hand provide a set of terms for describing some domain (Swartout et al, 1997) and they can be thought of as taxonomies of relevant objects within that domain. Example of domains may include aerospace, biology, manufacturing, arts etc.

2.2 Use of Foundation Ontologies for Ontology Matching

Foundation or upper ontology are being used to match concepts in two independently developed ontologies. The idea is to first match two ontologies with an upper ontology and then matching these two ontologies using the similarities existing between them and the upper ontology. The LOM tool

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developed by Li (2004) uses WordNet, SUMO and MILO to match two ontologies. Aleksovski et al (2006) use DICE ontology as background knowledge to match two flat unstructured lists of concepts. Mascardi et al (2007) present an algorithm which uses upper ontologies to align two heterogeneous ontologies. They also experiment with OpenCyc, SUMO-OWL and DOLCE as semantic bridges to match ontologies (Mascardi et al, 2010). All of these cases deal with situations where independently developed heterogeneous ontologies are matched by using an upper ontology through the process of semantic bridging. These bridges are built when individual ontologies are matched with the upper ontology. The research presented in this paper, however, proposes to build these bridges during the ontology development process by the domain ontology builders so as to provide the knowledge verification system with clues to establish concept similarity. The verification system in this way uses the foundation ontology as a dictionary to interpret ontology based knowledge across diverse domains as has been proposed in the research literature (Mascardi et al, 2007, 2010). To achieve this there needs to be provided a set of core concepts along with their prescribed use. This 'prescribed use' needs to be there to ensure that a trace is left of every domain concept or a combination of concepts to the foundation ontology counterparts and it is this dimension of the proposed verification framework here which distinguishes it from the rest of the research work described in this section.

2.3 Knowledge Verification

When formalized knowledge is shared between different domains, prevention of its subjective interpretation becomes necessary. This process of authentication of the interpretation, here, is referred to as knowledge verification. The description which endorses the sense in which the term verification is used here is the one given by Gupta (1993) where he mentions that knowledge verification involves the checking of completeness, consistency and correctness of knowledge. For this to happen during the cross domain knowledge sharing between ontology based knowledge bases, similarities first need to be established between the two ontologies. This leads to the need of an ontology matching and mediation system. The techniques these systems use are discussed next.

2.4 Ontology Mediation Techniques

The most crucial stage in the ontology mediation task is the similarity finding. Different mediation tools use different strategies and algorithms to achieve this purpose. These matching algorithms can be divided into four types (Aleksovski et al, 2006).

I. Terminological methods which are based on lexical matching of ontological concepts,
II. Instance-based methods where the lexical similarity of instances is compared in two ontologies,
III. Structural methods where the positions of different concepts in the structure of two ontologies are used to find matches and
IV. Semantic methods which use some additional logic to discover similarities.

Each of these methods or a combination of them is employed by the ontology mapping and matching tools to overcome mismatches that exist in independently developed heterogeneous ontologies. Two main types of mismatches that may come up when matching ontologies are explication and conceptualization mismatches (Visser et al, 1993). A closer look at the ontology mediation tools which use these similarity finding methods reveals that most of these tools are just able to overcome explication mismatches and even fewer do this automatically (Anjum et al, 2010).

The matching and verification technique explained in this paper partly resembles the fourth type of similarity finding methods explained here and it capable of overcoming not only the explication but also the conceptualization mismatches. This method includes the use of semantic information in the form of connections between the domain ontology concepts and their foundation ontology counterparts. These connections are established during the ontology building process. The challenge is therefore to make sure that some standard connections, like inheritance, are put in place during the ontology building stage for the verification system to make use of. This can be achieved through a verification meta ontology which is explained in the sections to come.

3 FOUNDATION ONTOLOGY MAPPING FRAMEWORK

This system is proposed specifically for domain ontologies formed by using the concepts from a foundation ontology. Figure 1 shows the schematic of this framework. The framework consists of three modules. The 'inheritance identifier', 'domain concepts identifier' and 'concept matcher'. The whole process of matching consists of six steps. The sequence of these steps is indicated in the figure through circled numbers. These steps are explained below:

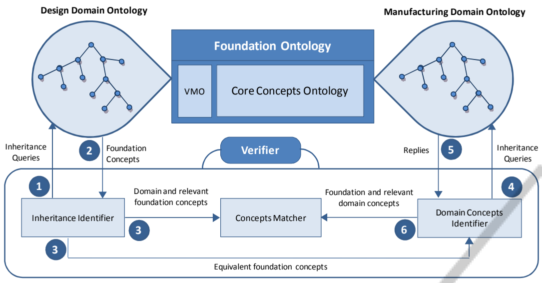

Figure 1: The Verification framework.

1- The process initiates with the generation of a query from the inheritance identifier. This query explores the foundation concepts behind a concept in the design domain ontology. This domain concept is the one which is required to be matched with a similar concept in the manufacturing domain ontology.

2- The inheritance identifier receives replies in the form of relevant foundation conceptualisations.

3- These foundation conceptualisations and relevant design concepts are then sent to the 'concept matcher' and to the 'domain concept identifier' at the same time.

4- The 'domain concept identifier' then generates a query to explore the concepts in the domain manufacturing ontology which possesses the same foundation concept inheritance.

5- The domain concept identifier then receives the replies in the form of domain concepts having the same foundation concepts as sent by the inheritance identifier.

6- These domain concepts along with their related foundation concepts are then sent to the concept matcher and concepts with similar foundation inheritance are declared as similar.

3.1 Verification Meta Ontology

The purpose of a verification meta ontology (VMO) is to police the use of concepts from the foundation ontology. This can be done by loading the foundation ontology and the VMO along with the newly developed domain ontologies in the ontology editing environment. In this setting the VMO scrutinizes all the concepts for traceability to foundation ontology and if a lag is found the domain ontology builders are notified. For example, when the concept of hole is referred to in the foundation ontology, as shown in figure 2, it can be given any name as long as it has enough semantic information about its origin in the foundation ontology and that is what the VMO controls.

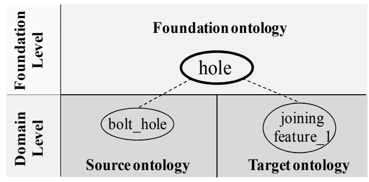

Figure 2: Foundation ontology subsumptions in domain ontology.

This VMO may consist of a few classes but predominantly a set of rules governing the use of concepts from the foundation. Through these rules, VMO performs the process of semantic enrichment of domain concepts. It makes sure that there is enough evidence or traceability of concepts formed in the domain ontology in order for them to be tracked back in the foundation ontology. The VMO needs to be built by the verification system builders keeping in view the contents and structure of the foundation and core concepts ontology.

3.2 A Possible Scenario

The example of a disc is taken here which is to be modelled in a domain ontology by using core concepts from the foundation ontology. Figure 2 shows the difference in interpretations of features of the same disc in design and manufacturing and how the same disc is modelled differently in two domain ontologies. The foundation for the concepts used in domain ontologies, however, are same for both design and manufacturing. The dotted lines show how the concept of 'disc_edge' feature is inherited from the foundation concept of 'rim'. Similarly 'diaphragm' is connected to the foundation concept of 'web'. Establishment of these inheritance relations can be made compulsory, through the verification meta ontology. This might be needed when a new concept is introduced in a domain ontology. Some examples of these inheritance relations can be:

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same_as
different_from
is_a_type_of
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It is through these relations and other compulsory attributes that the verification system proposed above will be able to track the identity of a concept in the foundation ontology and thus will verify the knowledge shared. The example given here is the

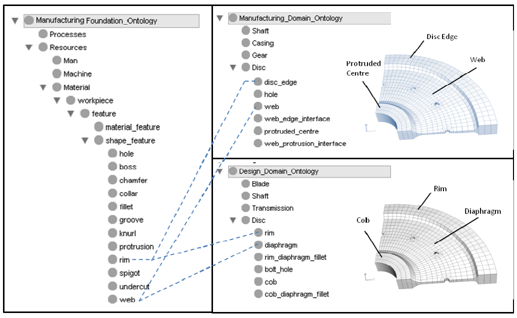

Figure 3: A possible scenario.

simplest possible case. More complex cases may include a totally different interpretation of features of a disc in design and manufacturing domains.

4 CONCLUSIONS

It can be inferred from the above propositions that a foundation ontologies need to come with a set of core concepts, a verification meta ontology and a knowledge verification system which interprets concepts across different domains by using the VMO rules. Domain ontologies developed by using this toolkit will be interoperable no matter what terminologies and combination of concepts they use to model entities. Knowledge associated to these models would therefore be shareable and verified.

The most important thing for this verification system to work is, therefore, the information and knowledge capturing. This is because it is that stage where the domain ontology concepts are semantically enriched for the verification system to work. The dynamic nature of this technique makes it much better than just mapping the similar concepts manually in two ontologies. The technique is dynamic because it allows the ontology builders to make changes and modifications during the life time of the ontologies without caring about its mappings with other domain ontologies. this is because if the changes made adhere to the prescriptions of the verification meta ontology they are easily interpretable by any ontology which is built on the same rules and uses concepts from the same foundation ontology.

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