A Logical Framework for Ontology Representation, Reasoning and Integration

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Research Area: Ontologies, Knowledge Representation, Semantic Web, Information Integration

1   The Aim of Research

- To provide the intentional explicit knowledge particularly for the control of subsumption consistency in ontologies.

- To present a hybrid knowledge representation formalism of domain ontologies in the order-sorted logic extended to the possible world semantics.

- To improve the role of ontologies for the semantically information integration.

2   Motivation

One of today's most pervasive and bedeviling IT challenges is to get "*the right information to the right people at the right time*". It is now recognized that physical and syntactic connectivity is not adequate, and networks among people, software agents and IT systems remain elusive. Many researchers agree that ontologies in particular and semantic-based technologies in general will play a critical role in achieving efficient information retrieval by knowledge sharing and integration through ultimately seamless connectivity. The trend of *Semantic Web* [Berners-Lee 2001] is a typical example for that.

The most commonly quoted definition of an ontology is "*a formal, explicit specification of a shared conceptualization*"[Gruber 1993]. In a translated version, it is a conceptual schema of a world, describing the clear definition of concepts, and relations among them that all encoded in a logic-based language for the purpose of knowledge sharing, reuse and semantic integration.

The success of Semantic Web and ontology-based applications is mostly determined by the quality of on-tologies, that is, the potential for expressivity, consistency, reasoning capability and complexity. Thus, a formal knowledge representation and reasoning system which provides those characteristics in a balanced manner, is essential for ontologies.

3   Our Approach and Idea

We first focus on the most fundamental problem in ontologies, that is, the subsumption consistency of concept taxonomies, which facilitates a well-defined knowledge structure and the efficient knowledge deduction. From the framework of *OntoClean* [Guarino and Welty 2001], the notion of identity is attractive for taxonomic analysis and we extended it by defining identity condition (IC) of each concept. We introduce the idea of multiple ICs through the IC inheritance, and apply it as the intentional explicit knowledge for subsumption consistency checking.

We integrate the order-sorted logic and modal logic to represent the ontologies because of the following reasons and advantages.

- Since the sorted logic is a first-order predicate logic with many ordered sorts, the classification of concepts into the partially ordered sets of individuals is natural in the logic.

- Sorting reduces the search space, by restricting the domains and ranges of functions, predicates and variables to subsets of the universe.

- All formulas with sorted terms can be checked more or less syntactically whether a logic program is well-typed or not.

- Since the web is populated with a number of ontologies and data repositories without central ed-

itorship and consensus, we view a domain ontology with independent semantics and populated databases as a local world and extend the sorted logic in the possible world semantics of Kripke frame.

Moreover, we embed the hybrid approach in our knowledge representation regarding with T-Box as a reference ontology and A-Box as an ontological database. It supports for the satisfiability checks of concept descriptions, and consistency checks of subsumption, disjointness and equality.

4   The Progress of Research

- We propose the *multiple ICs* for the taxonomic analysis and discuss about the IC-subsumption, incompatible IC and the consistent updating of ontologies in a given Kripke frame [1].

- We represent the sortal taxonomies in terms of order-sorted logic by considering the meta-properties (+R+I) as the predicates and the identity conditions as the unary functions of the sorted logic. Moreover, we discuss about the inheritance mechanism of ICs concerning with the lattice based taxonomies [2].

- We modify the alphabet, signature and semantics of the sorted logic by dividing sorts into the rigid and non-rigid sorts, and formalize the concept definition and relationships in the formulas of sorted predicates. Then, we prove the satisfiability of sorts, consistency of subsumption between sorts, and the soundness of our logic system in terms of Herbrand model. We also illustrate the dual subsumption in a hybrid knowledge model of ontologies [3].

- We give the specification of ontologies in the previous sorted signature, and highlight the role of *own IC* for the unification of sorts among independent domain ontologies. We provide the unification algorithm concerning with the sameness and mutual substitution of own ICs, and discuss about the complexity of unification process [4].

5   The Future Direction

In the future work, we are going to consider the following characteristics in our logic system.

- How is the computational complexity of reasoning for an arbitrary query process?

- How to embed the notion of IC and subsumption theory in the current ontology language systems such as DAML+OIL, OWL?

6   The Concluding Remark

The development of a single shared ontology with complete global agreement on terms and their meaning is elusive with many issues. In order for vibrant communities of semantically connected agents, business software applications, etc to emerge on a large scale, there needs to be a general infrastructure where one can easily register, access and use a number of ontologies, mapping between ontologies, ontology languages, and translation engines.

7   The List of Publications

[1] N. N. Tun and S. Tojo. *Consistency Maintenance for Ontological Knowledge Updating*. In Proceedings of *IEEE International Conference on Information Reuse and Integration (IRI-2004), ISBN 0-7803-8819-4, pp.388-393*, 2004.

[2] N. N. Tun and S. Tojo. *Inheritance of Multiple Identity Conditions in Order-Sorted Logic*. In Proceedings of *17th Australian Joint International Conference on Artificial Intelligence (AI 2004), Springer, LNAI 3339: Advances in Artificial Intelligence, ISBN 3-540-24059-4, pp.1187-1193*, 2004.

[3] N. N. Tun and S. Tojo. *Consistent Hybrid Knowledge Representation in Order-Sorted Logic*. In Proceedings of *International Conference on Computational Intelligence (ICCI 2004), IJCI Press, ISBN 975-98458-1-4, pp.349-353*, 2004.

[4] N. N. Tun and S. Tojo. *Unification of Sorts Among Local Ontologies for Semantic Web Applications*. In Proceedings of *4th WSEAS International Conference on Artificial Intelligence, Knowledge Engineering and databases (AIKED'05), and in the journal of WSEAS Transaction on Computers, Issue 2 Volume 4, ISSN 1109-2750, pp.123-129*, 2005.