Ontology Merging and Reasoning Using Paraconsistent Logics

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ABSTRACT

Dealing with the inconsistencies that might arise during the ontology merging process constitutes a major challenge. The explosive nature of classical logic requires any logic-based merging effort to dissolve possible contradictions, and thus maintain consistency. In many cases, however, inconsistent information may be useful for intelligent reasoning activities. In healthcare systems, for example, inconsistent information may be required to provide a full clinical perspective, and thus any information loss is undesirable. The authors present a 4-valued logic-based merging system that exhibits inconsistency-tolerant behavior to avoid information loss.

Keywords: Intelligent Reasoning Activities, Logic, Logic Based Merging System, Multi-Valued Logic, Ontology Integration, Paraconsistency

INTRODUCTION

Ontological knowledge bases are a knowledge representation (KR) style that has recently gained currency in the KR world, mostly spurred by Semantic Web (http://www.w3.org/) endeavors. The most prominent Semantic Web KR framework is the Web Ontology Language (OWL). For the present purposes, an ontology can be viewed as a formal theory formulated using the OWL language.

Ontologies have become widely effective for a range of applications, including software design, expert systems, database architectures, etc. The significance of ontologies has become well established in the healthcare and bio-informatics community, and the number of domain-specific, bio-medical, and healthcare ontologies is growing fast. An increasing number of them conform to various terminological standards. It has become a critical issue to share and reuse the combined but overlapping domain knowledge from the existing ontologies, especially those that conform to international
terminological standards. One way to deal with this issue is known as ‘ontology merging.’ This kind of integration is in high demand where the goal is to generate a single coherent ontology that ensures the maximum reuse of knowledge from multiple source ontologies.

The significance of ontology merging or integration can be observed in the context of the Pan-Canadian Electronic Health Record (EHR) system. EHRs enhance the flow of information across multiple healthcare disciplines through the use of clinical terminologies and uniform language. Because of the diversity of various clinical terminologies, the challenge is to find a single terminology to represent all of the care-providing disciplines. Canada, for instance, has adopted SNOMED-CT® as the recommended clinical terminology for the EHR. SNOMED-CT is a terminology maintained by the International Health Terminology Standards Development Organization (IHTSDO). The Canadian Nurses Association (CNA), on the other hand, recommends the International Classification for Nursing Practice (ICNP®) to represent nursing practice, as SNOMED-CT is more focused on the bio-medical perspective of healthcare. The CNA recommends that ICNP and SNOMED-CT collaborate to ensure that SNOMED-CT is developed in such a way so as to effectively represent nursing practice in EHR. This collaboration has recently materialized, among others, via the ICNP-SNOMED-CT mapping efforts currently underway under IHTSDO patronage. Merging or integrating ICNP and SNOMED-CT terminologies is invaluable for the overall success of EHRs to provide extensive representational capacity (Imam, MacCaull, & Kennedy, 2007; William, 2006).

A challenge for this kind of integration is to effectively deal with inconsistencies. Although the ontologies to be integrated are expected to be theories/descriptions of the same (or closely related) domain(s), they may have their own distinctive perspectives specific to their own applications. The terminological and theoretical differences can lead to various kinds of inconsistencies during the ontology integration process. Generally, inconsistencies are considered to be unacceptable. According to Bertossi, Hunter, and Schaub (1998), “all seem to agree that data of the form \( p \) and \( \neg p \) [where \( \neg p \) stands for ‘it is not the case that \( p \)’] for any proposition \( p \) cannot exist together, and that the conflict must be resolved somehow.” This attitude, however, comes as a consequence of the so-called ‘explosive’ nature of classical logics. In classical logic it is easy to show that anything (and therefore nothing useful at all) can follow (i.e., be inferred) from a set of inconsistent premises, which has been dubbed the ‘principle of explosion’ (e.g., Hunter, 1998). As classical logic has been the main basis for computer science theory and practice so far, the existing ontology integration systems (Su & Lars, 2002; De Bruijn, Martin-Recuerda, Manov, & Ehrig, 2004) are based on maintaining consistency. Although enforcing consistency may have advantages in some cases, there are many cases where it could be useful to promote various intelligent reasoning activities such as those identified in Bertossi, Hunter, and Schaub (1998): natural processes of argumentation, information seeking, multi-agent interaction, knowledge acquisition and refinement, adaptation and learning and so on. Most importantly, inconsistent information is useful to evaluate the advantages and disadvantages of different perspectives of expert knowledge. A paraconsistent logic is a non-explosive logic; in other words, it is a logic in which the fact that a sentence is both true and false does not lead to the derivation/inference of everything. The core motivations and the basic approaches for paraconsistent logics can be found in Priest and Tanaka (2009). In health care systems, inconsistent information may be required to provide a full clinical perspective where no information loss is desirable.

In this paper we present a merging system that has inconsistency tolerant behavior—hence avoids information loss. In order to develop such a system we took a non-classical logic-based and multi-valued approach to retain the maximum possible information. The rest of the paper is organized as follows. The next section motivates the choice of ontological knowledge...
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