Using OWL and Description Logics-Based Classification for Reasoning in Biomedical Applications

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Abstract

Anatomic reasoning tasks—such as inferring the consequences of penetrating injuries—is challenging because of the complexity and richness of anatomic knowledge. Applications that use ontologies for reasoning tend to be complex and difficult to maintain because the knowledge used to guide reasoning is embedded in the application code. Our hypothesis is that many reasoning tasks that use knowledge in ontologies can be posed as classification tasks and implemented using OWL and automatic classification. The benefit of this approach is that we can leverage emerging standard languages such as OWL for knowledge representation, and use high-performance domain-independent classifiers to implement reasoning services instead of creating complex domain-specific reasoning software. We demonstrate this approach by considering the task of anatomic reasoning about the consequences of penetrating injury. We have created two different reasoning applications that infer the anatomic consequences of injury using OWL and automatic classification. Our results highlight the advantages of posing reasoning problems as a classification task, and leveraging the automatic classification capabilities of OWL to create intelligent applications.

Solution Description

We have implemented two different types of anatomical reasoning services: (1) inferring abnormal blood flow through injury channels, and (2) functional impairment of the heart if arteries supplying it have been severed. We created in OWL a knowledge model of chest and heart anatomy describing the heart structure and the surrounding anatomic compartments. We also created a second OWL model that describes the perfusion of regions of the heart by branches of the coronary arteries. Both of these anatomic models were derived from the Foundational Model of Anatomy (FMA; Ross and Mejino, 2003), a frame-based representation of anatomy that we translated into OWL. We added additional knowledge in the form of class axioms and restrictions that provide logical assertions of the classes and properties of the classes that are necessary for reasoning. For example, we defined the conditions necessary for blood to flow between anatomic compartments (connectivity between the compartments and blood in the compartments), and we defined regions of the heart in terms of the segmental arteries that supply them. We then used a domain-independent classifier (RACER, Haarslev and Möller, 2001) to infer ischemic regions of the heart as well as anatomic spaces containing ectopic blood secondary to the injuries. Both reasoning services were deployed as Web services using the protégé API.

Discussion

In most reasoning systems that use ontologies, the knowledge used to guide reasoning (control knowledge) is embedded in the application code or in rules used in conjunction with the domain ontology (Golbreich 2004). Control knowledge and domain knowledge are in different places, making application maintenance and development of future extensions cumbersome. In order to extend or create reasoning applications, it is often simplest to create new ontologies or new application software.

We believe that it is advantageous to use description logics (DL) in biomedical applications to represent both the domain knowledge and the control knowledge needed for reasoning. Thus, we construe the reasoning problems in the domain as classification tasks. The reasoning application can also leverage high-performance classifiers to reason with the DL. This approach is advantageous because the classifier would not require any domain-specific knowledge, it could be reused in many other applications, and these applications would be easier to maintain.

The use of OWL in biomedical applications has to date focused on "terminological" aspects of knowledge; the formal semantics of DL have been used to infer classification taxonomies and to help identify inconsistencies (De Coronado 2004). We believe that classification as a reasoning method can also be suitable and advantageous in other types of intelligent applications provided the reasoning task can be posed as a classification problem. Specifically, our results suggest that inferring the consequences of penetrating injury can be formalized as a classification task.

There are benefits in using OWL as a representation language. OWL is an emerging standard, and reasoning applications can take advantage of high-performance classifiers such as RACER. OWL ontologies contain both a declarative model of the domain knowledge as well as explicit class definitions, properties, and axioms that specify the knowledge used in the classification task. Since all knowledge needed for reasoning is in the ontology, the application code can be reused among different reasoning tasks without modification. In addition, we were able to model our reasoning tasks in OWL simply by adding a few new classes and axioms to a single base OWL ontology—we did not need to develop specialized reasoning tools.

We found that separating the reasoning problem into two discrete tasks was helpful, because we could divide the larger problem into smaller modular components and work on them separately. In the future, we could combine the two OWL ontologies into a single ontology, particularly since both ontologies share the same base ontology. This modular approach to OWL ontology representation and reasoning service development could also be useful in tackling larger reasoning applications.

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