Development of an Ontology for an Industrial Domain

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ABSTRACT

This article presents a method for ontology construction and its application in developing an ontology in the domain of natural gas pipeline operations. Both the method, as well as the application ontology developed, contribute to the infrastructure of Semantic Web that provides semantic foundation for supporting information processing by autonomous software agents. This article presents the processes of knowledge acquisition and ontology construction for developing a knowledge-based decision support system for monitoring and control of natural gas pipeline operations. Knowledge on the problem domain was acquired and analyzed using the Inferential Modeling Technique; then the analyzed knowledge was organized into an application ontology and represented in the Knowledge Modeling System. Since an ontology is an explicit specification of a conceptualization that provides a comprehensive foundation specification of knowledge in a domain, it provides semantic clarifications for autonomous software agents that process information on the Internet.

Keywords: knowledge-based decision support system; natural gas pipeline operations; ontology development

INTRODUCTION

The vast amount of information on the World Wide Web has made it increasingly difficult to access and retrieve the required information or data. In response to the problem, the World Wide Web Consortium (W3C) formally proposed the Semantic Web to be the next evolutionary step for the Web in 2001. The Semantic Web aims to attach semantic information to Web resources and would provide the semantic structure or scaffolding that would enable autonomous software agents to traverse the Web in search of or process information on behalf of users or other systems.

Within this context, ontologies are important from at least two perspectives. First, they provide a key component of the Semantic Web because an ontology can function as a repository of vocabulary of unambiguous domain-related concepts and their meanings anchored in consensus domain knowledge (Jaspar & Uschold, 1999). This semantic structure would enable autonomous agents to access and process information on the Web. An example is the use of ontologies to support negotiation in e-commerce (Tamma, Phelps, Dickinson, & Wooldridge, 2005). Second, ontologies provide sharable knowledge models on particular problem domains for construction of knowledge-based systems in a distributed and open environment such as the Internet. Therefore, from the knowledge engineering perspective,
an ontology constitutes a crucial building block for developing knowledge-based systems.

Knowledge engineering is the process of eliciting expertise, organizing it into a computational structure, and representing it in a knowledge-based system. The process of knowledge engineering can be viewed from the cognitive informatics perspective (Chan, Kinsner, Wang, & Miller, 2004; Kinsner, Zhang, Wang, & Tsai, 2005; Patel, Patel, & Wang, 2003; Wang, 2002, 2003, 2006, 2007; Wang, Johnston, & Smith, 2002; Wang & Kinsner, 2006; Wang, Patel, & Patel, 2006; Yao, Shi, Wang, & Kinsner, 2006), with a focus on the problem solving expertise in cognition (Chan, 2002). The effort spent in engineering knowledge is often substantial due to the tacit nature of expertise; and the process of acquiring knowledge for building the knowledge base is widely recognized as a major bottleneck in the development process. If several knowledge-based systems on the same problem domain are to be constructed, the effort required to build the knowledge bases for the different systems is often duplicated. A possible solution for the problem is to share any knowledge on a given problem domain that has been acquired among systems. Four different approaches for sharing knowledge have been adopted within the Knowledge Sharing Effort sponsored by Air Force Office of Scientific Research, Defense Advanced Research Projects Agency, the Corporation for National Research Initiatives, and the National Science Foundation (Neches et al., 1998). Similar to their objectives, the work presented here aims to construct ontologies that can overcome the barriers to sharing that arise due to lack of consensus across knowledge bases on vocabulary and semantic interpretations in domain models. A critical step in the process of developing an ontology is performing a detailed analysis of the domain. In this article, we present a method for knowledge acquisition and ontology construction to support the development of a knowledge-based system, and we demonstrate application of the method to the domain of natural gas pipeline operations. The proposed method involves first eliciting and organizing knowledge using the Inferential Modelling Technique (IMT), and then—based on the initial classification of knowledge elements in the problem domain—constructing an application ontology using an automated knowledge modeling tool called the Knowledge Modeling System. The knowledge represented in the application ontology provides the basis for implementing the advisory system.

Long-term objectives of the work include developing a general method for ontology development that may be applied to other domains; contributing to the repository of application ontologies that can provide the basis for developing knowledge-based systems on the Internet; and contributing to the infrastructure needed to facilitate ontology development as part of the Semantic Web for autonomous machine intelligence. This article presents the process of developing part of the domain ontology for the natural gas transmission domain. Understanding the ontology development process of this application domain contributes to the long-term objective of deriving a method of ontology development by identifying the knowledge types in this domain. The assumption is made that natural gas domains share a set of common and basic vocabulary, even though different application problems can make use of particular subsets of the common vocabulary. The knowledge types clarified in this natural gas transmission domain constitute one such subset of the general ontology for the natural gas domains. Hence the question of whether this problem domain is typical of the natural gas problems is less important than the fact that this is one of the problems in the natural gas domain.

This article is organized as follows: The first section gives some background on ontological studies within the context of knowledge level modeling and knowledge acquisition. The second section briefly describes the application domain of natural gas pipeline network operations. The third section presents knowledge acquisition and initial classification of the knowledge using the IMT. The fourth section discusses knowledge representation using the knowledge modeling system. The fifth section...
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