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GUEST EDITORIAL

Special Issue: Developing and using engineering ontologies

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Engineering today is overwhelmingly a collaborative activity, often widely geographically distributed, in which different participants bring specialist viewpoints to bear on their engineering tasks. In the process, the participants generate and use large quantities of information, often making use of sophisticated computer tools. Important challenges in this context are the sharing of information and the effective application and interoperability of the tools. A key technological approach in addressing these challenges is the use of ontologies. There are various notions of what these allow, but they are widely seen as involving the development and recording of conceptualizations of domains of shared interest. Ontologies allow sense to be made of a domain of interest through definition and classification of key entities, properties, relationships, and their dependencies. They allow richer knowledge models to be developed, they facilitate the communication through such models, and they enable knowledge-based technologies that depend on semantic access to be developed and applied.

The application of ontologies has been widely explored in many domains, from art to zoology, and the associated technologies form the foundation for the enhancing of the World Wide Web through the Semantic Web. Engineering, which has also seen a good deal of development, presents a particular challenge. It is characterized by diversity, complexity, and multiplicity. It involves many stages, each of which has unique tasks and activities. In engineering design, in particular, the focus on the possible or potential leads to a strong emphasis on abstraction. As noted, the engineering enterprise is often interdisciplinary and geographically distributed, with tasks carried out in many different languages, and this may constrain access to domain experts for the purposes of ontology construction or verification. Thus, although there are almost certainly no problems associated with the development of ontologies for engineering that cannot be found elsewhere, engineering is perhaps unique in the combination of the challenges that are faced.

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The goal of this Special Issue is to explore a number of these particular challenges of the application of ontologies in engineering, especially to illustrate the diversity that characterizes the domain. This has been addressed through 6 papers, selected from 17 originally submitted for review, that illustrate issues from underlying philosophy to applications in specific branches of engineering. The papers were selected by double-blind reviews of each paper by at least three expert reviewers, and those papers that gained preliminary acceptance were reviewed again after resubmission to ensure that any critical comments by the reviewers had been considered. The review of manuscripts that included a coeditor as an author was managed exclusively in a screened manner by the uninvolved coeditor.

Key to collaboration in any domain is the shared understanding of the fundamental concepts of the domain, and in this regard the meanings of function and behavior are very important in engineering design. In their paper, Stefano Borgo, Massimiliano Carrara, Pawel Garbacz, and Pieter Vermaas present a formal characterization of these concepts in the context of technical artifacts, based on the meanings identified by Chandrasekaran and Josephson. In doing so, they demonstrate that using foundational ontologies to provide a common definition of core terms is well suited to the engineering domain.

The modeling of function and behavior are also central to the work of Ashok Goel, Spencer Rugaber, and Swaroop Vattam, who encompass also the modeling of structure, in their description of the structure, behavior, and function (SBF) modeling language. SBF takes a teleological approach, using a representation that specifies both the functions of the system and the causal processes that result in the system functions. The precise specification potentially enables a range of additional automated capabilities such as model checking, model simulation, and interactive guides and critics for model construction. In this paper, the abstract syntax and the static semantics of an SBF language are described, with a view to providing a basis for interactive construction of SBF models.

In the third paper we turn to the use of ontology for the support of general information sharing and reuse, in particular, for the structuring of unstructured engineering information to achieve more effective information retrieval. Zhanjun Li, Maria Yang, and Karthik Ramani describe a method to create and validate an engineering ontology for this purpose, presenting a systematic and structured ontology development method assisted by a semiautomatic acquisition tool and a comprehensive validation strategy. Their tool is integrated with the Protégé ontology editing environment. An engineering lexicon bridges the gap between the concept space of the ontology and the word space of engineering documents and queries. The effectiveness of the approach is demonstrated by a retrieval performance test.

Robert Harrison and Christine Chan's paper on a dynamic knowledge modeler is also concerned with general purpose knowledge modeling: in this case, dynamic knowledge. Static knowledge in a domain consists of observable domain objects (classes), attributes of classes, and relationships between classes. Dynamic knowledge consists of tasks (or processes) that manipulate the static knowledge to achieve an objective. The paper uses the inferential modeling technique embedded in Dyna, a Protégé plug-in, to model the static and dynamic knowledge elements of a problem domain and to provide support for dynamic knowledge testing and ontology management. Dyna is applied for constructing an ontological model in the domain of selecting a remediation technology for petroleum contaminated sites.

In the final papers we turn to the application of ontologies in two specific engineering domains. The first paper, by Kyoung-Yun Kim, Seongah Chin, Ohbyung Kwon, and R. Darin Ellis, presents a framework for the capture and propagation of assembly design and joint information in a robust approach for the modeling of mechanical assemblies containing joints of various types. It is based on the representation of morphological characteristics of an assembly in which assembly joint topology is defined using a mereotopology, a region-based theory for parts and associated concepts. The approach is implemented using Semantic Web Rule Language rules and Web Ontology Language (OWL) triples, and Web3D is employed to support sharing of assembly geometry, demonstrating the use of semantically enabled Web technologies to support collaboration.

The theme of distributed collaboration is continued in the paper by Jakob Beetz, Jos van Leeuwen, and Bauke de Vries, describing the application of ontologies in the Building Information Modeling domain. This paper demonstrates how ontologies can be built upon existing information and data modeling approaches, lifting modeling information from the EXPRESS family of languages used in the informally named STEP family of engineering standards. The reported research shows how the ontology Web language and related technologies can be tailored to the needs of distributed collaborative work in the building and construction industries, and demonstrates the benefit of using an ontological approach by showing how generic query and reasoning algorithms can be used where previously hard-wired application approaches were necessary.

From the collection of papers in this Special Issue of *AI EDAM* we observe a focus in research on finding the most successful method for defining effective and valid ontologies. Approaches to finding this method vary from adopting a particular modeling paradigm, to defining detailed procedures, to developing techniques for conversions from existing knowledge resources. We do not yet observe a clear convergence of the methods and languages used for defining and managing ontologies, although the availability of a variety of tools for working with OWL, such as Stanford's Protégé, has stimulated its acceptance as a standard. This, in turn, supports a shared understanding of the role and functioning of ontologies in engineering and design processes. Although progress has been made with respect to the issues of defining ontologies and reusing existing resources, other challenges remain, such as knowledge discovery and interoperability of knowledge intensive engineering tools.

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