Advanced Engineering Informatics 27 (2013) 1–3

Contents lists available at SciVerse ScienceDirect

Advanced Engineering Informatics

journal homepage: www.elsevier.com/locate/aei

Editorial

Modeling, extraction, and transformation of semantics in computer aided engineering systems

With the rapid advancement of information and internet technologies, engineering software systems are now commercially available to aid engineering tasks, such as design, analysis, integrated manufacturing, and requirements modeling. Recent trend in computer aided engineering (CAE) includes the integration and smooth communication between existing CAE systems [1], management of knowledge for different engineering tasks across disciplines [2], and development of natural human–computer interfaces [3]. In addressing these challenges, ontology and semantic web have been widely developed and used by researchers in various fields [4–8]. Particularly, research results have been focused on four aspects: (1) modeling and representation of engineering information that can effectively support the extraction of semantics [9–12]; (2) conceptual structure of engineering information that embodies the semantics necessary for various engineering tasks [13–17]; (3) algorithms for transforming different representations of engineering information into semantic conceptual structures [18,19] and (4) innovative applications [20,21].

The focus of this special issue is on emerging technologies that can be used to extract useful knowledge or information for CAE applications from heterogeneous contents including documents, graph, geometry, and CAD drawings. In this special issue, seven research articles are included by addressing the aforementioned four research topics.

To model and represent semantics, Raskin et al. present a meaning- and ontology-based approach. In their paper titled ‘‘Meaning- and Ontology-Based Technologies for High-Precision Language: an Information-Processing Computational Systems’’, the need for an ontology- and meaning-based approach is addressed for computational systems that can understand and process information in natural language. An example of an air crash is used to show that a disaster may happen when meaning is not accessed or accessed inadequately, for instance, without disambiguation. By discussing the very nature of meaning which tends to be taken for granted, misunderstood, and confused with formalism, the Ontological Semantic Technology proposed by the authors was introduced for possible applications to computer aided engineering applications. Particularly, the importance of and approaches to accessing implicit information by machines are discussed. This paper, which is contributed by authors outside of engineering fields, may stimulate the engineering community to look at the semantics from a different perspective.

Zhang et al. highlights that design rationale (DR) information plays a very important role in the design reuse, design decision support and design analysis, in their paper titled ‘‘A Semantic Representation Model for Design Rationale of Products’’. From the point of view of semantic representation, their paper analyzes and discusses the semantic concepts and relationships abstracted in the Issue-based Information System (IBIS) model in detail. The presented work extends the traditional IBIS model, introduces the Semantic Web technology into the DR representation, and proposes a new DR semantic representation model, the ISAA model, by combining the traditional concept model with formal semantics. They also provide a formal definition of rules for concepts, relationships and relation constraints, which expands the semantic representation capabilities provided by the Web Ontology Language (OWL) and lays the foundation for reasoning and verifying DR information. A semantic annotator integrating with the visual product design model was developed, by which the discrete information of thinking is captured and abstracted to a conceptual representation of the ISAA model.

To realize proper conceptual structure of engineering information that embodies the semantics in engineering applications, Wen et al. propose a method to online collaboration, named Cross-Language Transformation based on Recursive Object Model (CLT-ROM) in their article, titled ‘‘A Model Based Transformation Paradigm for Cross Language Collaborations’’. The method is an attempt to answer a fundamental question: ‘‘What is understanding and how to understand the understanding?’’ They focus on the understanding process. The goal of the paper is to explore the fundamentals of semantic technologies and extract useful requirement knowledge or information from the heterogeneous content including documents in a cross-language environment. Based on the model-based transformation paradigm for cross-language collaborations, the authors present a prototype of the model-based transformation method and examples that illustrate the feasibility of the method.

In computer-aided engineering systems, the data complexity residing in various engineering systems has increased dramatically in terms of size and diverse formats. Interoperability between these systems has been a significant barrier of semantic integration of engineering data. The article of Song et al. highlights the primary reason of this semantic interoperability caused by structural and semantic heterogeneity in their paper, titled ‘‘An Ontology-Driven Framework towards Building Enterprise Semantic Information Layer’’. They establish a framework to develop a global semantic layer for heterogeneous data sources. The Semantic Information Layer includes three components: ontology extraction and enrichment, ontology alignment and mapping accessibility and querying implementation. Interestingly, this paper tackles semantic extraction and formalization issues related to legacy information systems based on their holistic ontology alignment method. The authors address a methodology to align ontology with relational database, for which majority of engineering data is systematized. Their

1474-0346/$ - see front matter
http://dx.doi.org/10.1016/j.aei.2012.12.001

methodology builds semantic information layers on the relational database, by using the dynamic multiple strategies-based ontology alignment (dmsOA). The dmsOA method adapts multiple existing strategies and similarity aggregation methods. The Semantic Information Layer obtained by their methodology facilitates heterogeneous computer-aided engineering systems in a more semantically interoperable manner.

As an algorithm to manage semantic assembly design rules, Choi and Kim present an article, titled "Disparate Attributes Algorithm for Semantic Assembly Design Rule Management". Noticeably, ontology has been used as means of sharing and integrating information and knowledge of product design. One of major challenging issues of design knowledge sharing with ontology is the creation and use of heterogeneous ontologies. To expedite the increase of availability and interoperability, traditional computer-aided design (CAD) systems have developed structured neutral data. In addition to such efforts to resolve the trade-offs between the heterogeneity and interoperability in use of ontology, another challenging issue is to deal with complicated design rules in implementation of ontologies. To efficiently use large-scale semantic design rules and facts, Choi and Kim present a method that reduces the rules' complexity and improves reasoning time. Rule complexity reduction methods include redundancy elimination and eliminating inconsistency reduction for the relationships of conditional attributes. Authors introduce a new rule management algorithm, called Disparate Attributes Algorithm, to consider the semantic rule complexity issues by extending rough set theory. The results show that the algorithm is able to handle complex design rules with minimal loss of any inducing capability of the design rules. The disparate attributes algorithm leads to a minimal set of rules by decreasing the rigidity of the rules. This set of simpler rules can have multiple advantages vis-à-vis the capability to handle incomplete information, and the classification of unique features among various attributes.

In this special issue, two articles address very interesting semantic applications. Song and Jiang present a proactive search system for computer-aided engineering applications in their article, titled "Proactive Search Enabled Context-Sensitive Knowledge Supply Situated in Computer-Aided Engineering". Modern engineering software systems are powerful in functionality, but they have grown to be so complex that a lot of knowledge is required to manipulate them. As evidence, a great number of questions seeking CAE guidance are asked on the web. To realize more natural interaction between human and systems and the exploitation of Internet content to solve engineering problems, authors aim to channel relevant online knowledge to an engineer who may be facing difficulties in his CAE task, helping him to save time that would otherwise be spent on query formulating and waiting for a response. As to methods, authors design a goal-context scheme for engineering knowledge and its application condition, and substantiated it by applying information extraction to the Internet content. Usually, to provide knowledge support during an engineering task's processing, one cannot escape the elaboration of what procedures and resources are involved in the task and the specific conditions for applying every knowledge piece. Such elaboration can be heavy work and often impedes the development of knowledge reuse systems. Their work facilitates problematic situation and knowledge demand recognition without a prior thorough understanding of the target engineering task and relevant knowledge discipline. Concretely, this article uses concepts captured from engineering software's GUI (graphical user interface) to construct queries and search the web, and the semantics related with a concept are extracted from the search result through natural language parsing. Several heuristic rules are employed to weave concepts together and detect the problematic situation where a specific knowledge piece can apply. Authors implement the proposed method in Java and tested it with FEA (finite element analysis) tasks. Results show that the method has a good chance to improve an engineer's knowledge concerning FEA.

Tessier and Wang highlight the importance of instance-level verification, which causes ambiguity in CAD data exchange in their paper, titled "Ontology-based Feature Mapping and Verification between CAD Systems". The existing research has focused on feature-based data exchange. Their article attempts to represent feature classes and properties and systematically classifies them by a reasoner in the target system, without using any or little knowledge about the source system. Authors propose a three-branch hybrid feature model to model a CAD feature in terms of the individual settings and parameter values selected by the user during feature definition. The three-branch hybrid feature model serves as a template to describe a feature using the shared base ontology language. In their article, a syntax model for the three-branch hybrid feature model with a directed labeled graph is presented. The semantic model of the feature ontology is also defined with a set of feature concepts compatible with Ontology Web Language (OWL) and Semantic Web Rule Language (SWRL). To show how the proposed framework can be achieved computationally, PTC's Pro/Engineer CAD software was used for the export of features into the shared base CAD ontology format. A sample set of feature classes were created to demonstrate a local ontology feature hierarchy. The SWRL rules were implemented in Protégé-OWL's SWRLTab and run using the Jess rule engine. The article shows feasibility of the hybrid feature model to provide a balance between prescribing a neutral format while maintaining the expressiveness and individuality of each CAD system.

While this special issue includes up-to-date concepts and technologies to model, extract, and transform semantics in computer-aided engineering, remaining challenges have been also identified. The first challenge is how to efficiently capture semantics without compromising the quality of the captured model from a designer. The second challenge is how to extract the designer's model from a large volume of raw data. Specifically, design semantics from multiple cultural, social-technical background significantly increase the data complexity. Thus, additional research is required for the scalable methods.

We would like to take this opportunity to thank the authors for their valuable contributions and sincere cooperation by responding often rigorous reviewers' comments. The extended efforts to improve the quality of papers are appreciated. We must also thank our reviewers for their careful and patient reading and reviews of the submitted articles during many rounds of review. Their highly constructive feedbacks enabled the quality of articles.

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Available online 11 January 2013