Advanced Engineering Informatics 29 (2015) 472–482

Contents lists available at ScienceDirect

Advanced Engineering Informatics

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

Developing taxonomy for the domain ontology of construction contractual semantics: A case study on the AIA A201 document

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ARTICLE INFO

Article history:
Received 6 November 2013
Received in revised form 10 March 2015
Accepted 21 March 2015
Available online 16 April 2015

Keywords:
Ontology
Semantics
Taxonomy
Contractual management
Construction claims

ABSTRACT

In construction contractual management, sharing experts' domain knowledge through ontology is a good way to narrow the knowledge gap between the domain experts and the construction team. However, little work has been done on ontology taxonomy development in this domain. Based on a literature review on sharing domain knowledge, taxonomy development methods and the essence of construction contracts, this study proposes a synthesized methodology for taxonomy development in the domain of construction contractual semantics. This methodology is based on an ontological model extracted from definitions found in the contract, and uses common root concepts as the initial root concept classes, and includes the iterative development and competency questions approaches as well. In the case study, using the research results from pilot studies, the proposed methodology was applied to the AIA A201 General Conditions of the Contract for Construction (2007) document at the textual level. As a result, a taxonomy was developed which was used to determine the validity of the proposed methodology. The taxonomy development methodology and the developed taxonomy itself are both valuable contributions in the quest to further develop ontology-based applications for sharing domain knowledge about construction contract semantics.

1. Introduction

The development of more sophisticated buildings and building systems has led to more complex and consequently, more risky projects in the Architecture/Engineering/Construction (AEC) industry. This trend has made project contract management much more difficult, and consequently, claims and legal issues have become more and more unpreventable due to the increasing complexity and uncertainty involved in construction projects [25]. Further, for the project contractual parties, the performance of contract management duties and avoidance of contractual claims have an important impact on project success. Contract management requires domain experts' with comprehensive contract knowledge and professional insight. However, due to the restrictions of the project jobsite, a knowledge gap exists between the domain experts and the construction project team. For example, in practice, the personnel given the role for managing claims are in most cases, because of the uncertainty of a claim arising, selected in an ad-hoc manner, as opposed to having dedicated personnel in that role similar to estimators, planners and accountants [45]. Therefore, it is fairly common to find that in most cases, these claim clerks are lacking in claim-related professional knowledge and experience and consequently substantial errors and omissions often occur in the claim preparation process. For example, an inexperienced clerk might easily miss or ignore some facts or proofs which can have impacts on the outcome of certain type of claim cases. Those mistakes usually lead to a loss of the claim. In other words, the aforementioned knowledge gap heavily impacts the performance of project contract management duties. Narrowing this knowledge gap, by representing the experts' knowledge through ontology and sharing it with the contract management team is a good way to solve this problem [34]. At the initial phase of building this domain ontology, a solid taxonomy is necessary to classify and organize the related concepts in the contractual relationships between project parties. Currently, there exist some legal ontologies at the general level, however, little work has been done on building the taxonomy for the domain construction claim analysis. Considering the significant amount of particular engineering and management background knowledge involved, which is out of the boundary of purely general law, the existing legal ontologies have very limited applicability in this scenario. Therefore, the decision was made to start with creating a domain taxonomy from scratch for this study.

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http://dx.doi.org/10.1016/j.aei.2015.03.009
1474-0346/

According to the conceptualization process in the two prevailing ontology developing methodologies [38,17], the task following the building of a glossary of terms is building a concept taxonomy (often referred to as "define the classes and the class hierarchy"). This task is the most important one in the ontology development process, since taxonomy is a Knowledge Organization System (KOS) serving as the "backbone" of the domain knowledge for organizing concepts. To develop the taxonomy for the domain knowledge of construction contractual semantics, this study proposes a synthesized methodology. This taxonomy development methodology starts from an ontological model generalized from fundamental contract law principles; and then utilizes the common major root concepts to categorize the concepts that appear in the target contract documents. In order to preserve the capability to collaborate with other taxonomies, the major root concepts used in popular top level taxonomies and/or classifications (e.g. IFC) are utilized to initialize the development of this taxonomy. In order to determine the scope limitations of the taxonomy and to assure consistency of its terms, the following two approaches are also used: competency questioning [22] and iterative development [21]. Finally, the validity of the proposed methodology is tested through a case study that applies it to the textual content of the clauses of the AIA A201 General Conditions of the Contract for Construction document [1]. Furthermore, based on the taxonomy developed in this research, together with a rule-based NLP methodology, a particular application was developed to semantically interpret impact factors for construction claim cases.

2. Literature review

2.1. Expert systems for sharing domain knowledge

In the construction arena, one of the traditional methods for sharing the domain knowledge about contractual issues is by using expert systems (ES). Based on the theories about knowledge representation and logic reasoning, mainly production systems and frames, ES can present and reuse domain knowledge to some extent. To be specific, with the development of expert systems in the 1980s, a great number of studies on the application of expert systems in construction contract and claim analysis were conducted from the mid1980s to the mid1990s. Table 1 shows a brief timeline of these expert systems that was developed based on an extensive literature review.

Table 1
Timeline for expert systems development in construction claims.

Year	Authors	Expert systems developed
1984	Diekmann and Kruppenbacher	DSCAS
1984	USA-CERL	CGS-DSC
1986	Cobb and Diekmann	CEKS
1987	Alkass and Harris	Claim Expert
1987	Emojong	About Contractual Bonding
1988	Kraiem	DISCON
1989	Alshawi and Hope	Extension of Time under JCT80
1989	Arditi and Patel	Framework for Export System for time-related disputes
1989	Bollock	NOTICE
1990	Smith, Hanna and Bullock	NOTICE2
1991	Riad, Arditi and Mohammady	Conceptual Model for Knowledge-based Expert Systems for time-based claim management
1992	Diekamnn and Gjertsen	CGS-SEA
1992	Diekamnn and Kim	CGS-SuperChange
1993	Alkass, Mazerolle and Harris	An integrated system for time-related disputes
1994	Cooper	Claim Advisor
1995	Alkass	CDCA

Almost all of the ES are rule-based and make use of the logic reasoning relationship among concepts. However, due the disadvantages of its knowledge representation theories, this methodology has shortcomings related to representing and sharing domain knowledge. The knowledge representation level achieved by ES is too shallow to reach the level of being semantically accessible and interpretable by machine. This shallowness mainly manifests itself in the inability of representing the concepts themselves. All of these ES do not represent knowledge from the base level of legal concepts that govern litigation outcomes [33]. To make up for this defect, the common practice used with ES is to just throw this problem back at the user by simply asking the user to figure out the concept interpretation and judgment. However, this practice makes it necessary for those using these so-called expert systems to be real experts, which defeats the purpose of using an expert system [8].

The reason for this shallowness is that common-sense knowledge can be difficult to represent in ES [19]. Some measure of common sense knowledge can be represented but it must be done explicitly. However, one would have to explicitly enter all such knowledge, which can be impractical in most situations. The reason behind this problem is the absence of a global language which allows the knowledge bases to be shared by all systems. With a global language, the lack of implicit knowledge deemed as "common sense" in one domain can be fulfilled by sharing the explicit "non-common sense" knowledge in the other domains. Just like the explanation about the relationship between ontologies and expert systems from W3C, it is somewhat parallel to the relation between the Web and hypertext community – based on some of the same motivations, but with a very different architecture that drastically changes the ways in which the technology can be deployed. Later, even though the agent-based approach was proposed in the negotiation of construction claims, the importance of domain ontology for knowledge was also emphasized [39]. All of these problems show the necessity of using ontology and its ability to share domain knowledge in the area of construction contracts and claims. It is necessary to clarify that although ES and ontologies are different things and not exactly counterparts, in terms of solving the problems of sharing domain experts' knowledge, they both serve as influential methodologies chronologically.

2.2. Taxonomy in ontology development

A meaningful result of the development of ES in the Artificial Intelligence realm in the 1980s is that, capturing knowledge for a powerful knowledge-based system has become more and more important, which has led to the initial usage of the term ontology to refer to the modeled body of knowledge. Gruber [20] first coined the term "ontology". After that, a large body of knowledge regarding ontology from theory to methodology has been developed.

As far as the methodology for building ontology is concerned the first guidelines for developing ontologies, ENTERPRISE Ontology and TOVE (Toronto Virtual Enterprise), were proposed by Uschold [43] and Grüninger and Fox [22] respectively and refined later [43,44]. However, these guidelines were only applicable to the case studies involved and did not set a standard for all situations.

Depending on the characteristics of different domain areas, the process of building ontologies can vary. Subsequently, additional theories about the methodology of ontology building were developed based on different domains. The influential ones include: KACTUS methodology [7,24] for reuse of knowledge about technical system during their life-cycle in the manufacturing and engineering domains; IDEF5 (Integrated Definition for Ontology