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Experience modeling with graphs encoded knowledge for construction industry

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ABSTRACT

The Architecture, Engineering and Construction (AEC) industry is becoming increasingly knowledge intensive. Knowledge management has been hailed as an enabler for tapping this knowledge to improve efficiency in the AEC industry. In this study, the main concepts and benefits of knowledge management, relationships between knowledge management and continuous improvement have been examined. Furthermore, emphasis has been laid on knowledge management through experience feedback processes which constitute valuable assets for the AEC industry. This is done through the employment of ontologies and graph-based reasoning operations in eliciting and visualizing knowledge concepts in the AEC domain. The proposed approach which consists of two main aspects provides the opportunity to examine the conceptual and ontological knowledge models with associated reasoning. In the first, the concepts of knowledge management, their significance and application in the AEC field are discussed. The second deals with a methodological framework for the modeling and reasoning in the domain ontology. To facilitate automation, an ontology graph-based editor, Conceptual Graphs User Interface (CoGui) was used to model knowledge and encoded reasoning in the knowledge base. CoGui encodes knowledge as conceptual graphs and reasoning as graph operations that can be visualized in a logically precise way, based on domain ontologies. It emerged that CoGui could be very useful in acquiring information that can be used in collaboration with others to continuously improve information sharing and re-use. A French AEC company located in the Southwest region was employed as a case study in illustrating knowledge modeling through the experience feedback process. For each phase of experience feedback, actions that were implemented in the company are discussed.

1. Introduction

In the past, there has been no structured approach to learn from construction projects once they have been completed. Nowadays, the construction industry is adopting a sustainable strategy by using knowledge management concepts and techniques to improve the organization of knowledge from completed projects [9]. Knowledge can be seen as the means to extract and capture the available information which can be used to provide better and efficient ways of improving processes, producing and/or delivering construction products (e.g., buildings). For instance, experiences that relate lessons learned of how well a product could be produced, maintained, used and so forth [12]. Knowledge-based quality improvement involves experience feedback methodology that can be applied with three key methodological elements: (a) analysis with a set of tools; (b) a stepwise problem-solving method and (c) using common metrics [7]. With regards to the first, recommended tools include statistical techniques (e.g., design of experiments and regression analysis), and non-statistical tools (e.g., flow charts and fishbone diagrams, or both). A stepwise problem-solving offers a systematic analysis and impacts learning and knowledge creation and consists of the following steps: problem identification, diagnosis, solution generation and implementation. Furthermore, stepwise problem-solving technique provides models for problems visualization and systemic understanding of their main characteristics and the reasoning options available. The interaction between continuous improvements, experience feedback processes and stepwise problem-solving procedures leads to knowledge creation from structured learning processes [34]. Common metrics aid coordinate knowledge creation efforts by incorporating and aligning

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the problem-solving process aim at improving interaction and offer pragmatic solutions in work related situations. Despite the merits of the afore-mentioned experience feedback methodologies, common major challenges related to computing in civil and building engineering still exist. Tizani and Mawdesley [32] reported that (a) enhancing digital information modeling; (b) extending process modeling technologies; (c) improving decision–implication analysis, (d) integrating broader aspects of experience feedback processes are still quite common. Furthermore, in the field of civil engineering, studies about experience feedback tend to focus on structural aspects with little interest in preliminary stages of facilitating works. In France, experience feedback is more common in the field of industrial engineering than in AEC. The main reason is the automation of production systems in industrial engineering, compounded by the fact that industrial products often have similar characteristics.

It has been hailed that solutions for most knowledge management challenges lie in information and communication technologies (ICT). The increasing availability and quality of ICT; for example, the internet, underlying communication and emerging technologies are transforming the way people share knowledge and ideas. The ease of use and characteristics of these technologies have made them very popular in a very short period of time. However; compared to other industries, the AEC industry lags behind with regards to the successful implementation of ICT and in tapping the potential of the new and/or innovative technologies to improving productivity, achieving greater efficiency and higher quality [22]. Thus, knowledge of products, services and/or processes from past AEC projects are hardly fully exploited for use in other projects leading to information duplications, inconsistencies and inefficiencies in delivering such projects. This study aims to employ an ontology-driven approach to develop a knowledge management model for construction projects. The model will serve as a knowledge-based decision support system. To facilitate understanding, the paper is divided into four sections. Section 2 provides a background of the state-of-the-art about knowledge management applications in the construction industry. Section 3 presents an ontology-driven approach for knowledge modeling in the construction AEC industry. In Section 4, an illustrative case study is employed to depict the methodology and concepts of experience feedback. The discussion and analysis of major issues covered in this manuscript are discussed in Section 5. The conclusion is presented in Section 6 by a way of summary of the key parts of the paper.

2. State-of-the-art

2.1. Generations of knowledge management applications in the AEC industry

Knowledge management is recognized as a key resource and a crucial enabler for continuous process improvement in construction projects. It has been widely acknowledged that one of the key sustainable advantages that a firm possesses comes from what it collectively knows, how efficiently it uses what it knows and how readily it acquires and uses new knowledge. Organizational knowledge could reduce the time spent on problem-solving and increases the quality of work. Recent developments in ICT have prompted organizations to utilize platforms such as corporate intranets and collaborative extranets for collaborative knowledge sharing. Companies are also implementing extranets to share information of experience feedback scenarios expressed for explicit knowledge capitalization and exploitation. In these situations, experience feedback is useful in terms of how well the organization works in many aspects, from learning knowledge from experience feedback information and using it in improving management strategies. The preceding statement underscores the difference between information and knowledge management. The right knowledge management adoption strategy should be put in place to develop and nurture core organizational competencies, and create intellectual capital by tapping or capturing experience feedback information. It has been argued that a true value creation culture can be found through the right combination of human networks, social, intangible and technology assets where issues such as change management, learning and trust must be blended successfully towards the vision of knowledge-enabled value creation. There has been an evolution of knowledge management over time [25]. The differences of the evolution are examined in Table 1.

In certain circumstances (e.g., the scarcity of specific data), it is not possible to move towards reliable analytical or statistical approaches [14,19] and experience feedback approach is then adopted as a more suitable alternative. However, Aamodt and Plaza [1] recommend that there must be a reasonable number of experienced cases that are sufficiently similar to be grouped together for potential application of the reasoning process over its underlying knowledge for use in new cases or projects. This underpins the concept of "experienced feedback".

2.2. Knowledge management through experience feedback

The usefulness of information structuring and knowledge capitalization from experience feedback in solving engineering problems have been examined in Gardoni et al. [10,11]. The experience feedback process consists of three essential steps (see Table 2): (i) the capitalization phase, (ii) the treatment phase, (iii) and the exploitation phase. In Table 2, the first two stages consist of capitalization and a synthesis of different stages of treatment in experience feedback. The third is about the exploitation phase of feedback for fault diagnosis systems, safety assessment (levels of protection), and forecasting changes in equipment over time.

In order to generate knowledge from experience feedback, a conceptual model [15] incorporating problem-solving to generate explicit knowledge from experiences is presented in Fig. 1.

Table 1
Three generations of knowledge management in the AEC industry.

Generations of KM criteria	Generation 1: knowledge sharing	Generation 2: knowledge conceptualization and nurturing	Generation 3: knowledge value creation
Underpinning ICT	Human interpretable knowledge systems (knowledge embedded in documents requiring human interpretation)	Semantic based systems(articulated around the use of Building Information Modeling or ontology)	Systems managing knowledge as an asset(leveraging the intellectual and social capital of an organization)
Socio-technical dimension	Information and communication technology	Human and organizational factors	Human networks, social capital, intellectual capital, technology assets, and change management
Lifecycle focus	Software application focus	Discipline focus	Total lifecycle and AEC domain focus
Knowledge perspective	Condition perspective emphasizing access to information	Knowledge process perspective focusing on knowing and acting	Capability perspective: knowledge is a capability with a view of creating value