An Approach for Identifying and Evaluating Opportunities Offered by Semantic Technology to BIM-enabled Online Collaboration Platforms

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ABSTRACT

Through a demonstrated attempt to identify and evaluate opportunities offered by semantic technology to Online Collaboration Platforms (OCPs), a context-specific requirements engineering process is developed and documented. Seven illustrative functionalities are proposed and evaluation of their demand and feasibility has indicated potential challenges such as access to data from other projects, the need for controlled workflows and the utility of standard data models. The approach can be developed to evaluate technical feasibility as well to ultimately characterize the natural contribution of semantic technology to OCPs.

INTRODUCTION

Background, problem and context-specific issues. Across all industries and application types, semantic technology promises significant productivity improvements along with a paradigm shift in the way technology users interact with information. The architecture, engineering, construction and facilities management (AECFM) industry, characterized by a geographically distributed, multi-disciplinary workforce generating and exchanging a vast amount of diverse project information, requires sophisticated collaboration tools, and can benefit significantly from semantic technology. Abanda et al. (2013) provide an extensive review of research relating to Semantic Web for the built environment since 2000, demonstrating the variety of intended application domains (e.g. project management, smart homes, urban planning), intended software media (e.g. software for design, simulation, coordination, facilities management) and functionalities (e.g. reasoning, code-checking, archiving, retrieving and model extraction).

Current practice across AECFM does not utilize the potential demonstrated within research initiatives. Furthermore, the opportunities arising from semantic technology specifically for the family of software known as construction Online Collaboration Platforms (OCPs) can come closer to realization if a more formal, hence more communicable and more improvable approach for their identification and evaluation is adopted. Two issues which emerge as a result of natural traits of AECFM (project specificity and project-led nature, inadequate standardization, discipline fragmentation, life-cycle phase fragmentation) and emergence of cloud-based solutions are: (1) Cross-project variation in both high-level software configuration (what combination of software to use) and low-level software configuration (which part of each software to use). The vague distinction between the roles of software calls for an approach supporting flexibility (from the perspective of project set-up) and prioritization (from the perspective of software development). (2) Requirements engineering for cloud-based solutions tends to be a combination of moving existing functionality to the cloud as well as devising novel, "fit-for-cloud" functionality.

Aim, approach and methodology. This paper focuses on OCPs and provides a mechanism for bridging the gap between promised opportunity and realization. Through a demonstrated attempt to identify and evaluate opportunities offered to OCPs by semantic technology, a context-specific requirements engineering process is developed and documented. The focus is not on technical issues (e.g. developing or extending ontologies or schemata) but rather on technology and domain literature mapping. "Solving a problem simply means representing it so as to make the solution transparent" (Simon, 1981). Following this notion, this paper attempts to solve the technology implementation problem by providing suitable representations of different aspects of the problem. The steps followed are outline as: (1) deduce the pre-requisites for an effective semantic functionality and the stakeholder context (2) understand the nature of opportunities offered by Semantic Technology in AECFM (3) identify a suitable representation of the role of OCPs in BIM process, (4) identify a number of illustrative, OCP-specific functionalities and (5) devise a method for evaluating these functionalities.

LITERATURE REVIEW: NATURE OF PARADIGM AND OF BENEFITS

Pre-requisites for an effective semantic solution. An effective semantic solution is defined as a solution provided by a software system which is enabled by a computer interpretable knowledge representation (ontology) and provides value to the software user. Based on a review of literature (Berners-Lee et al.,2001; and Allemang & Hendler, 2011) a simplified model of the pre-requisites for an effective semantic solution was developed for the purposes of this research (figure 1).

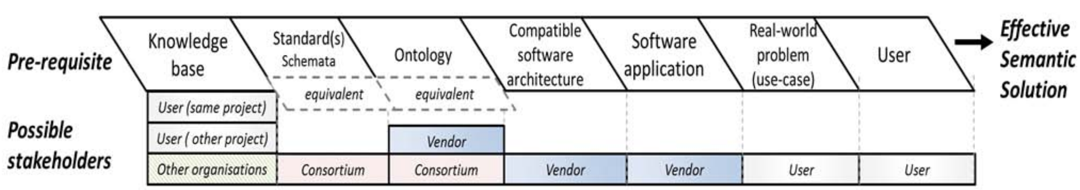

Figure 1. Model of basic pre-requisites for an effective semantic solution

The model demonstrates that typically: (1) an effective semantic solution results from the contribution of a diversity of parties whose effort and benefit is not necessarily aligned and (2) within the "Standards" and "Ontologies" domains there doesn't exist exclusivity amongst possible instances for a given solution. This highlights the need for harmonization in this joint effort if effective semantic solutions are to become more widespread.

Opportunities for OCPs and nature of benefit. Acting as the hub for project information which is typically diverse, unstructured and is continuously updated to satisfy varied information exchange needs, OCPs could benefit considerably from semantic technology. The diversity of applications and benefits found within AECFM research is demonstrated by Abanda et al. (2013). A number of studies address issues relating to online collaboration by developing capabilities such as model-document integration (Caldas et al., 2004), conformance requirements organization (Yurchyshyna et al. 2009), document indexing (Elghamrawy and Boukamp, 2010) and configurable model exchanges (Venugopal et al., 2013). A general framework for semantic web-based information management (Anumba et al., 2008) aims to “enhance collaboration, avoid information loss, overload and misunderstanding”. Through this diversity of applications, a universal pattern is that once the benefit is realized a “new” type of waste, a waste of semantics (meaning), is eliminated and becomes observable through its absence.

There is evidence of infrastructure for (Beetz et al. 2011) and applications of (Vanlande et al. 2008) semantic technology within some forms of collaboration software. However framework-setting studies (Singh et al., 2011) and studies focusing on requirements from commercial, browser-based Online Collaboration Platforms (Liu et al., 2011; and Shafiq et al., 2013) do not address semantic technology. Therefore, this study sets out to devise a formal requirements engineering approach which accounts for the, often changing, role of OCPs within the BIM process as well as the natural traits of semantic technology and AECFM.

THE OCP AND ITS ROLE IN BIM PROCESS

OCP and their core “BIM Use Purposes”. OCPs are the combination of web-based technologies “that create a shared interface, to link multiple interested parties, to share, exchange and store project information in digital form, and to work collaboratively, on the basis of subscription fee, license plus maintenance, negotiated fixed cost or exclusive business partnership agreement” (Liu et al., 2011). In order to facilitate a rational approach for deriving semantic technology-enabled functionalities for OCPs, the role of OCPs in the BIM process is expressed in terms of the “BIM Use Purposes” developed by Kreider and Messner (2013) (figure 2). The guiding criterion was “which Use Purposes require the sharing of information between collaborating parties”.

Heuristics for enhancing OCPs. The following served as heuristics for evaluating and improving the service of OCPs: (1) Integration of content (e.g. model- document integration, tagging), (2)Integration of features (e.g. BIM-based procurement), (3) Controlled workflow (e.g. content distribution process automation, controlled revisioning of content), (4) Role-based configuration, (5) Flexible workflow, (6) Intuitive experience/environment, (7) Visibility/transparency, (8) Easy access to relevant information, (9) knowledge management(KM): intra-project, (10) knowledge management(KM): inter-project and (11) Mobility.

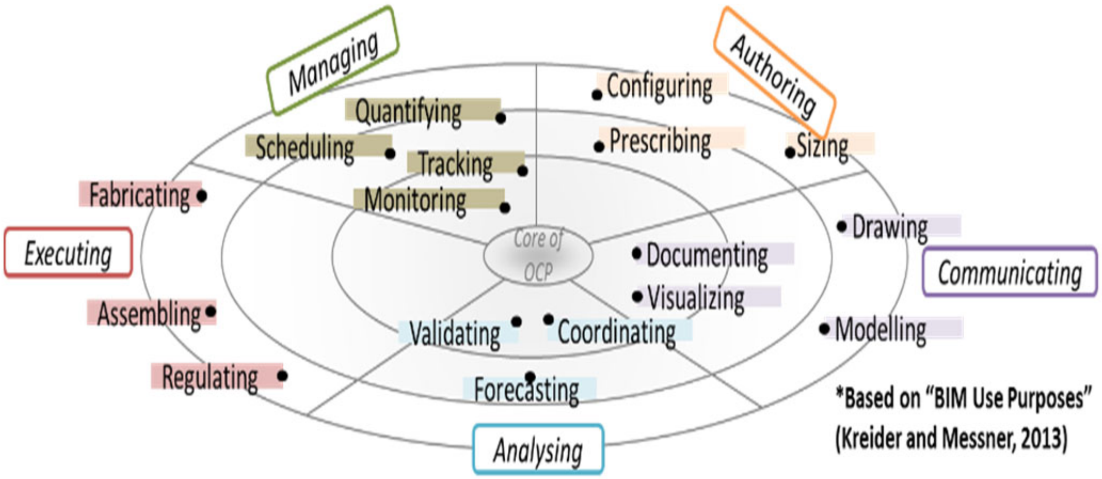

Figure 2. The role of OCPs in the BIM Process in terms of "BIM Use Purposes"

IDENTIFYING AND EVALUATING OPPORTUNITIES OFFERRED TO OCPS BY SEMANTIC TECHNOLOGY

Identifying opportunities: some illustrative use-cases/functionalities. The Core OCP BIM Uses Purposes (3.1), were coupled with the heuristics for enhancing OCPs (3.2) to devise seven illustrative applications of semantic-web technology (e.g. (1) Role-based Semantic Searching) inspired from the capabilities demonstrated in literature (see Appendix A, columns: "Functionalities" and "Supported BIM Uses and Heuristics followed"). These were used for demonstrating the utility of the following steps in the approach (4.2 and 4.3).

A fitting representation of opportunity: value as waste elimination. Value to the user can be represented as waste elimination and, in this case, elimination of "waste in meaning "or "cost of inadequate semantic interoperability" (2.2). Elucidation and evaluation of this waste can be achieved by comparing current technology and process to counterfactual scenarios where semantic interoperability is present. The "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry" (NIST, 2004) provides a useful tool for this approach. Specifically "Table 4-1: Summary of Technical and Economic Metrics" was used as a basis for evaluating the seven illustrative functionalities identified in (4.1).The adapted table is presented in Appendix A.

Evaluating opportunities: gathering expert opinion. Separate semi-structured interviews with three Asite Implementation Consultants were conducted to inform Appendix A. The consultant's experience on software configuration and consultancy to users was used to assess (1) the perceived level of demand from users, (2) potential value (in the consultants' view) and (3) the level of disruption to existing processes from the implementation of the seven proposed functionalities. Interviewees were given a 40 minute presentation covering the basics of semantic technology and simple mock-ups illustrating the seven functionalities. The latter part included discussion with clarifications, and feedback and recommendations for refinement. At the end, the interviewees were asked to complete a response sheet where they ranked the seven functionalities in terms of the three categories and provided comments.

RESULTS AND DISCUSSION

Results from interviews. Preliminary results and indications arising from this stage of the research are: (a) The most valued and demanded from the illustrative functionalities, according to the implementation consultants, relate to searching and content associations. These represent enhancements of existing features. (b) Cross-project/workspace data access was considered disruptive. Amongst comments and discussion the biggest barriers were (c) data privacy and (d) the openness/availability of data for the knowledge base. The former highlights a chronic barrier to BIM and knowledge management while the latter highlights the utility of the IFC data model and its subset, COBie in "unlocking" the data in the knowledge base. (e) The need for controlled workflows is not accounted for in the proposed recommendation style use-cases.

The approach and its utility. The approach - outlined in Figure 3 - allows for the incorporation of any BIM Use, a likely revision given the dynamic nature of the BIM software industry. Additionally, it explicates the waste elimination potential of proposed functionalities in a way in which the impact on different users/collaborators at different phases can be assessed. The approach can be developed to map waste on a project phase-user group-activity category framework, as in NIST (2004) (see "Figure ES-1, 3D framework"). As a result, this can help characterize the natural contribution of semantic technology to OCPs.

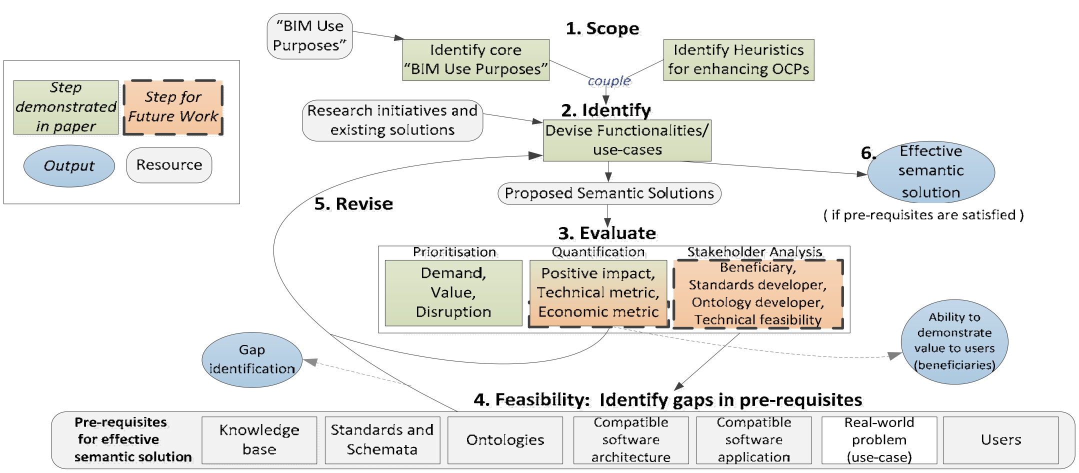

Figure 3. Outline of approach.

Main limitations of approach and execution. (1) The illustrative functionalities were neither exhaustive nor representative of the diversity of potential opportunities. (2) OCP users were not engaged at this stage of the research. (3) The technical feasibility was not assessed (thereby omitting some basic pre-requisites)

CONCLUSION

BIM Use Purposes were selected as a language for scoping the role of OCPs in BIM and combined with OCP-specific heuristics to devise illustrative use-cases. Their value can be represented as semantic waste elimination and quantified by adapting the NIST (2004) framework. Their relative importance can be identified by surveying experts (and users in future work). The captured process can help communicate the approach, track decisions and revise the approach. Within the OCP vendor, it helps compare current ways of working to a semantic technology-enabled state and characterize the natural contribution of semantic technology. Additionally it can serve as a mechanism for communicating gaps and aligning pre-requisites within the industry. Ultimately, the approach can form the basis for an automated requirements elicitation system, given the availability of repositories and codification of resources.

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APPENDIX A – Evaluation of waste elimination from semantic technology-enabled functionalities in OCPs

Functionality	Demand	Value	Disruption	Positive Impact	Technical Metric	Potential adverse effects/ inconsistencies	BIM Uses supported	Heuristics Followed
(1) **Semantic search with search recommendations** e.g. role-based e.g. project phase-based	=2	2	7	Elimination of information overload from irrelevant retrieved resources. Benefit of additional relevant resources User's time in looking for semantically associated resource	Precision (bigger fraction of relevant resources amongst retrieved resources) Recall (bigger fraction of relevant retrieved resources amongst all available resources). User seconds	• Info overload (from recommendations) • Overreliance	○ Tracking ○ Coordinating ○ Validating	○ Intuitive environment ○ Integration of content ○ Easy access to info ○ Visibility ○ KM Intra-project
(2) **Recommended or automatic associations of content** e.g. based on tag meta-data e.g. based on ontology meta-data e.g. based on content	1	=3	4	User's time in associating content Benefit from association of otherwise non-associated content	User seconds (In design) design decision accuracy (in finding content) user seconds	• Info overload (from recommendations)	○ Coordinating ○ Tracking ○ Validating	○ Integration of content ○ Intuitive environment ○ Visibility/transparency ○ KM Intra-project
(3) **Notification of relevant content in other project workspace**	7	7	1	User's time in associating content Benefit from association of otherwise non-associated content	User seconds (In design) design decision accuracy. (in finding content) user seconds	• Info overload (from recommendations) • Data privacy issues	○ Validating	○ KM Inter-project ○ Visibility/transparency
(4) **User/role-based recommendation for recently uploaded documents**	6	5	2	User's time in finding the content (if user seeks for it) Benefit from using otherwise "missed" content	User seconds Various, not specified	• Disrupts protocols for content distribution (existing automated processes)	○ Qualifying ○ Tracking	○ Role-based configurability ○ Intuitive environment ○ Easy access to relevant info.
(5) **Recommend individual in project team based on model/document content or meta-data**	=2	6	3	User's time in finding individual Benefit from engaging individual (if otherwise not engaged)	User seconds Various, not specified	• Disrupts protocols for content distribution (existing automated processes)	○ Validating ○ Coordinating	○ Role-based configurability ○ KM Intra-project
(6) **Recommend standard, guideline or regulation based on model/document content or meta-data**	=2	1	5	User's time in looking for standard Benefit from finding relevant standard (if otherwise not engaged)	User seconds Various, not specified	• Over-reliance	○ Validating	○ Easy access to relevant info.
(7) **Recommend listed supplier for object within model**	5	4	6	User's time in looking for supplier Benefit from finding relevant supplier (if otherwise not found)	User seconds Various, not specified	• Most contractors have preferred suppliers	○ Prescribing	○ Integration of features ○ Role-based configurability

* Columns/fields for future work: "Economic Metric", "Technical Feasibility" and "Supporting Ontologies"