Title:
Architectural Knowledge Modeling: Ontology-Based Modeling of Architectural Topology with the Assistance of an Architectural Case Library

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Introduction:
BIM applications have gradually replaced CAD software as a means of solving complex information integration problems in different disciplines of AEC industry. As communication platforms for design knowledge, however, most BIM cannot achieve formal representation of architectural design knowledge, especially what are different from engineering and construction. In traditional DBD (design-bid-build) process, architects package knowledge within drawings, which isolates architects' contributions from engineers, fabricators and constructors [3]. Once the knowledge expressed by drawings is lost after being converted to BIM, it is very difficult for architects to protect their contributions in the decision-making process. When architects cannot explicitly share and validate their knowledge during their negotiations with other disciplines, the BIM-based IPD (integrated project delivery) inevitably causes architects to be marginalized [4].

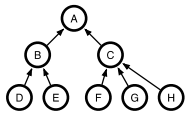
Based on the initial proposal of Eastman [2], BIM should be composed of three types of design information: semantic, topology and geometry. Topology of BIM consists of the mathematic connections between components, and functional definitions of parametric modeling [3], and is the key to the conversion of the three types of architectural design information [7]. Unfortunately, because conversion processing of design information is implicit and packaged within architects' drawings, while definitions of topology are usually ambiguous and vary with different architects. As a consequence, necessary objects and topologies for design computation, especially during the early and conceptual design stages, are usually ignored by current BIM applications, and this impeded the architectural application of BIM.

This paper is a follow-up study to two previous projects, "Smart Spatial Ontology" (SSO) [6] and "Visual Architectural Topology" (VAT) [7], and aims to develop a knowledge-representing tool entitled "Architectural Knowledge Modeling" (AKM) for the purpose of encoding architectural design concepts with the assistance of a house case library termed "Open Case Study" (OCS) [8]. By applying previous results, AKM aims to establish a formal representation of design objects and their topologies, which the assistance of unpacking and sharing architects' design knowledge in decision-making processes.

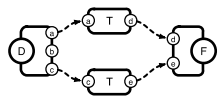
Main idea:
Present support of BIM in conceptual design is to reduce details and parameters of models. By reducing the level of details (LOD), it is useful for lowering recognition loading of learning and operating. However, the aggregating hierarchies of components in most BIMs are still major obstacles in architectural applications. For example, spaces and zones are generative features of floors and walls in most BIMs, rather than the topological manipulations for generating or controlling physical components necessary for early conceptual design stages [1][7]. One potential method for explicitly representing design concepts is the algorithm-based parametric design tools, such as Rhinoceros' Grasshopper plugins, which can assist architects in exploring geometric possibilities through the visual

composition of algorithms [5]. But similar to complicated input in BIM, however, the visual compositions of algorithms are still too complex to be intuitively recognized and associated with abstract concepts. The gap between algorithms and design concepts is thus a disadvantage when applying algorithm-based tools as a medium for communicating with other stakeholders. For presenting implicit concepts within drawings and communicating with other stakeholders of a project, architects typically apply other visual media, which usually consist of a series of diagrams or precedents representing their design beliefs and intentions. Since these media are separated from drawings, they cannot be directly converted into and validated in BIM.

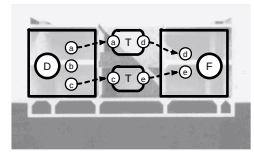
Therefore, employing previous research results and knowledge extracting from the OCS library, this paper proposes an ontology-based but moderately formalized tool that can assist architects in associating design concepts with case information and parametric algorithms. Rather than providing a rigid framework of an ontology [1], this approach is based on (1) open aggregating hierarchies of semantic ontology, (2) graphic linkages of topological relations, and (3) visual association of geometric features of design cases (Fig. 1). Based on SSO's ontology, graphic annotating interface of VAT, and visual information of design cases in OCS, the AKM project aims to develop a visual tool helping architects to represent the architectural topology of design concepts. AKM improves the open interpreting tool of ontology and topology in OSC into a manipulable communicating media, which is able to represent, explain, and validate architects' design beliefs and intentions. Via the semantics of SSO's ontologies, visual annotations of VAT, and associations among rich media of OCS, AKM can help architects to communicate with developers who wish to apply algorithm-based tools for geometric exploration, and with co-workers in other AEC disciplines who use BIM or other tools for detailed design and development.



(a) Semantic ontology of objects;



(b) Graphic annotations of topology;



(c) Geometric features of cases;

Fig. 1: Approaches of AKM.

Conclusions:

The MacLeamy curve, which the best publicity of BIM was shown in 2007 CURT by HOK's CEO, reveals that earlier decisions in the design process have a greater impact on the quality and cost of a project. Architects therefore win the design rights to a project or are invited to join an IPD team based on their creative insights. While BIM has gradually become a communication platform of AEC industry, applying BIM to represent creative design concepts may not only be costly and time-consuming for architects, but also make it harder to protect their painstaking work. It is therefore unsurprising that algorithm-based modeling tools like Grasshopper are popular with architects, who are willing to pay the cost of converting conceptual models into BIMs in order to safeguard their contributions. Although algorithm-based modeling tools are useful for exploring complex and elaborate geometric forms, other forms of conceptual knowledge, which clients and other disciplines can understand and accept, are also essential for architects to survive in the practices.

The AKM project in this paper illustrates our approach to improving representation of design knowledge through associations with the OCS library. Modeling results obtained using AKM enable visual communications among stakeholders, and can serve as an assistant during the early design stages. Before an architect can devote himself to algorithmic compositions of parametric tools or parametric modeling of BIM, it is necessary to represent and validate conceptual knowledge involving design beliefs and intentions [9]. AKM can not only add critical architectural topology absent in BIM, but also provide a foundation for development of the next generation of design assistance tools, which can associate abstracted design objects and their topology with algorithmic compositions and parametric modeling of BIM.

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