Automation in Construction 58 (2015) 196–206

Contents lists available at ScienceDirect

Automation in Construction

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

Integrated system for BIM-based collaborative design

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ARTICLE INFO

Article history:
Received 3 October 2014
Received in revised form 28 June 2015
Accepted 21 July 2015
Available online 15 August 2015

Keywords:
BIM
Collaborative design
Integrated design system
Data exchange
IFC

ABSTRACT

For effective collaboration among construction project participants, the use of Building Information Model (BIM) has become more common throughout the building life cycle. However, due to the use of different BIM-based software among collaborators during the design, a variety of problems have occurred, including loss of data, difficulty in communication, and poor work efficiency. Hence, this study proposes an integrated design system for the improvement of BIM-based collaborative design. For this purpose, problems are derived based on an analysis of conventional BIM-based collaborative design. In addition, a concept for the development of the BIM-based integrated design system is established from integration methodologies. Based on 'functional integration,' 'integrated information management' and 'integrated process support,' the integrated design system is implemented through the combination of three modules: BIM Modeler, BIM Checker and BIM Server. To test the integrated design system, a case study on a hospital building design is reviewed, and improvements compared to the conventional system are examined. It appears that the proposed system can enhance design quality and productivity by providing necessary support for collaborative design in an integrated manner.

1. Introduction

As construction projects become larger and more complicated, the amount of information required dramatically increases. As a result, various problems such as difficulty in collaboration and information sharing among project participants have taken place. To solve these problems, a variety of BIM-based technologies and applications have been proposed [5,22,28,36,60].

BIM was introduced based on the concept of storing and managing various data produced throughout the building life cycle in an integrated manner [12]. The geometric and property information of building objects is modeled upon solving design errors that frequently occur during conventional paper-based design and difficulty in information exchange in the collaborative design process [27]. In BIM-based collaborative design, therefore, it is essential to exchange design information between various participants (e.g., architects, engineers, contractors, clients, etc.) for making decisions. So far, however, participants in BIM-based design use different software according to work type and tasks in general, resulting in data loss in the process of information exchange, and this requires unnecessary duplication of work for data restoration [44]. Consequentially, unlike the ultimate purposes of BIM, due to limits in the application of BIM, the whole design process is still separated by phases and participants, which often causes additional cost and the inability to finish on schedule [12].

The design tools supporting BIM-based collaborative design should provide integrated functions that can be used throughout the design process. In addition, the information produced during collaborative design should be provided to participants in a timely manner. The integrated function and information in collaborative design make communication among design participants smooth and improve design quality and productivity by preventing unnecessary work. However, commercial BIM-based design tools used in practice are inadequate at providing a design environment from the perspective of integration, and most related studies have focused on information sharing using standard formats. Therefore, this study attempts to conceptualize integration for the improvement of BIM-based collaborative design and to propose an integrated design system. For this purpose, we derive problems based on analysis of conventional BIM-based collaborative design, and establish a concept from integration methodologies for the development of the BIM-based integrated design system.

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http://dx.doi.org/10.1016/j.autcon.2015.07.015
0926-5805/

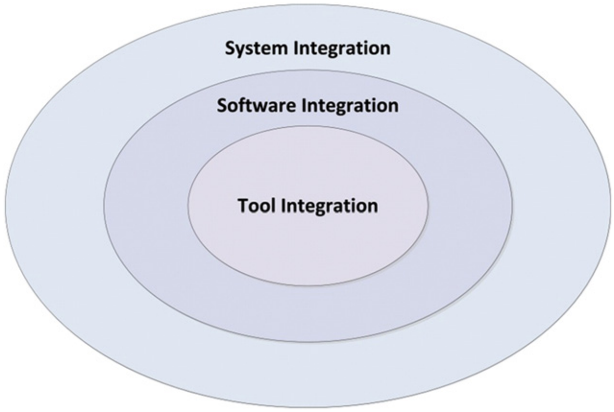

Fig. 1. Hierarchy of integration [53].

2. Current approaches in integration

2.1. Software and system integration

The lexical meaning of ‘software integration’ is “making disparate applications work together to produce a unified set of functionality” [24], and ‘system integration’ is defined as “the process of connecting systems, devices and programs together in a common architecture so as to share and exchange data” [58]. As such, system integration is a concept that includes software integration (Fig. 1). Therefore, the integrated system should be able to provide services to users in an integrated manner based on the software developed by unifying the tools that provide individual functions under a single system [53].

Software and system integration aims to provide services meeting user needs and demands and to improve work efficiency. There have been studies on integration in various fields under diverse categories. Table 1 summarizes studies related to software and system integration by category and field. The surveyed methodologies are largely classified into five areas: process, information, network, technology & function, and time.

Chapman and Kihn [10] emphasized information integration for the improvement of work efficiency, while Frances and Garnsey [15] tried to integrate information and functions for system integration. In construction as well, there have been studies on the necessity of an integrated environment for efficient collaboration. In his study on the effects of integration on the quality of buildings, Furgusson [19] defined integration as “flow of information and knowledge, taking a full life cycle view of the industrial facility development process.” From a similar standpoint, Flager et al. [14] studied design optimization through process integration.

In particular, Stavridou [53] defined system integration as ‘integration of tools and software’ and the studied relationships between components, data, processes and services (i.e., functions) of the integrated system. The study emphasized that components should include integrated functions that should be available across the life cycle, and data exchange should be possible between system components. He also insisted that integrating processes to provide services should be required. Jovanov [26] developed a network technology for reducing information loss between mobile devices. Using a similar approach, Proth et al. [46] proposed a server network technology for information exchange between software whereas Racu et al. [47] conducted a study on developing an automotive design process by using a timing model between software components. As such, network-based integration [21] can also be classified as information integration, and time-based integration can also be classified as process integration.

As shown in Table 1, there have been many studies on integration methodology in various fields. Even though the standpoint of integration is defined differently depending on the characteristics and purpose of study, these studies emphasize the integration of ‘function,’ ‘information,’ and ‘process’ directly or indirectly (Fig. 2).

2.2. Integration in BIM applications

In general, Architecture/Engineering/Construction (AEC) design collaboration includes participants from diverse fields and is executed using software applications (or systems). The concept of integration has been applied to the development of BIM applications, and Table 2 summarizes studies on BIM-based integration. The studies in this table deal with the functional integration of individual software for particular tasks or IFC-based information integration.

Information sharing through the IFC file format has many constraints in actual collaborative design, leading to diverse attempts to solve this problem. Lim et al. [37] and Kim and Ock [29] derived problems through the analysis of information compatibility using the IFC file format for BIM-based software such as ArchiCAD, Revit, MicroStation and Digital Project. Plume and Mitchell [45] analyzed IFC-based software interoperability during design, and Fischer and Kam [13] tested the interoperability between the IFC format and diverse commercial programs through analysis of actual cases. These studies reveal that the data loss occurs because the IFC format-based information exchange fails to provide complete interoperability. Often data loss has resulted from structural differences between the IFC format and the software's own data format or differences in data conversion mechanisms. Consequently, there have been limitations in developing a collaborative design environment through the IFC format.

Table 1
Studies on software and system integration.

Study	Process	Information	Network	Technology and function	Time
Racu et al. (2007) [47]					●
Zeidner (1988) [62]			●		
Beyne (2006) [7]				●	
Bolcer et al. (1996) [8]	●			●	
Chapman et al. (2009) [10]		●			
Flager et al. (2009) [14]	●				
Frances et al. (1996) [15]		●		●	
Furgusson (1993) [19]	●	●		●	
Hasselbring (2000) [23]		●		●	
Jovanov (2006) [26]			●	●	
Lee et al. (2000) [33]				●	
Noureldin et al. (2004) [43]		●		●	
Proth et al. (1997) [46]			●		
Schoner et al. (1992) [52]		●			
Stavridou (1999) [53]	●	●		●	
Terwiesch et al. (1999) [55]					●
Yoo et al. (2008) [59]		●	●		