A BIM-Based Collaborative Design Platform for Variegated Specialty Design

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A BIM-based building design collaborative platform for variegated specialty design

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Abstract:

With the increase in complexity of engineering projects and design quality in construction industry, the traditional two-dimensional “Information Island” approach to design is becoming less able to meet current design needs due to its lack of coordination and information sharing. Collaborative design using a BIM technology platform promises to provide an effective means of designing and communicating through networking and real-time data sharing.

This paper first analyzes the shortcomings of the two-dimensional design process and the potential application of collaborative design. By combining the attributes of BIM, a preliminary BIM-based building design collaborative platform is developed to improve the design approach and support a more collaborative design process. A real-life case is presented to demonstrate the feasibility and validity of the platform and its use in practice. From this, it is shown that BIM has the potential to realize effective information sharing and reduce errors and therefore to improve design quality. The BIM-based building design collaborative platform presented is expected to provide the support needed for the extensive application of BIM in collaborative design and promote a new attitude to project management.

Keywords: BIM; collaborative design; collaborative platform; information sharing.

1. Introduction

Building design involves complex and comprehensive work that requires the cooperation of variegated specialties, including architectural design, structural design, mechanical and electrical design. With the rapidly increasing size of projects, especially in China, building design is becoming increasingly difficult and complex. The traditional approach to building design begins with a preliminary architectural design that is used as a basis for the specialty designers to follow. In order to ensure consistency, a preliminary design review is usually conducted in which a chief designer who is experienced and familiar with the type of building involved gathers the requirements of the specialty designers. The intention is that the various designers involved will then keep in contract with each other, while the chief designer coordinates their work so that, if one specialty designer makes a change, the other affected specialty designers are all informed of the change made.

The traditional means of design collaboration is by transmitting information through the medium of two-dimensional paper-based drawings and associated documents. However, because the design specialties are usually separate and independent business entities, there is a reluctance to invest much time and effort in collaboration with each other, resulting in a lack of efficient communication channels. The effect of the shortcoming is manifested in what is termed “Information Islands”, in which much of the information possessed by each specialty is not communicated to, or accessible by, the other specialties. Many mistakes occur as a consequence of this breakdown in communications.

The effects of this on the design organizations are twofold. The first concerns the lack of collaboration [1]. Since the design work of one specialty is not understood by the other specialties, any change in one specialty design that is not communicated in a timely way can result in reduced productivity and waste of resources by other affected specialties. The second is related to repetitive work [2]. The repeated modification of one specialty design creates more work for other affected specialties leading to increased design costs. Conflicts may also emerge during the construction phase, cause a slowing or halting of construction work due to insufficient design information or rework when designs change.

A major focus of the construction industry today is on developing a means of countering these two effects to improve the quality and efficiency of building design. A current approach is on greater *collaborative design*. Collaborative design concentrates on the process of coordination and cooperation of designers from different specialties as a means of attaining the design goals in the most efficient and effective way.

Collaborative design has been the subject of several studies carried out at home and abroad. Cai [4], for example, summarizes the concept and principles of collaborative design including life cycle management, integration of resources and application of information technology, building a kind of new architecture design process model [14]. Zhang [3], on the other hand, analyzes three modes of collaborative design: three-dimensional design, document sharing and platform management, with platform management considered the most fundamental mode involved and AutoCAD, as the main designing software, used as the platform for collaboration [3]. For document sharing, Zhou [5] has compiled procedure files to simplify the process of document sharing depending on the adoption of Visual Lisp - a visible development environment integrated into AutoCAD. CAD platform-based systems such as Zhou’s [6] view management system and Gu’s [7] permission management have also been developed to coordinate information sharing and exchange and to manage the permissions involved in the design. Hu [8] introduces XML engineering documents to enable better the information exchange between designers and puts forward several solutions to eliminate conflicts, while external reference has been used to breakdown the design work and ease the process of updating drawings [9].

Other conflict management work involves a method of conflict model building and detection based on a Design Structure Matrix (DSM) for collaborative design Liu [10]. A cooperative design management system based on video conference has also been developed [11]. In this system, the standard of engineering design flow is established and project information and resource sharing is realized by developing additional functions in the existing collaborative platform. Further work involves the use of a Command-Dispatching and Process management (CDPM) system to manage and configure the process and the resources involved in collaborative design by workflow [12, 13].

As this review indicates, current collaborative design is mainly focused on two-dimensional design. Problems such as the lack of a unified standard [15] and shortage of available software [16] still exist. In order to improve the quality and efficiency of the design, new concepts and technologies need to be applied. As a new kind of design concept, Building Information Model (BIM) has been widely used in the construction industry. Since BIM has advantages of visualization and conflict detection [17], the application of BIM to parametric design and collaborative design [18] has also been studied. For example, in the industrialization of building to solve the problem of information management and transmission [19], conflict detection of mechanical, electrical and plumbing MEP work [20] and building information platforms [21]. According to current research on BIM-based collaboration, problems such as missing and faulty of information transmission still exist. In the next sections, the advantages of BIM are combined for use in collaboration design in order to construct a building design collaborative platform for an improved mode of collaboration.

2. Advantages of BIM in collaborative design

The emergence of BIM is bringing great changes to the design process. The traditional two-dimensional design is being transferred into three-dimensional design, which has the potential for the increased cooperation of each specialty designer. Three main advantages of the application of BIM in collaborative design are apparent: visualization for design, parameterization for modeling and collaboration for multi-specialty, as follows.

2.1.Visualization for design

The actual building component can be presented digitally from the BIM system. A three-dimensional entity model can be used to analyze the architectural image and functional layout to select the optimal architecture scheme. The modeling and construction drawings of each specialty can be carried out with their respective professional software, and linked to a unified model in the collaborative platform. With the duplicating and monitoring capability of BIM, design changes can monitored by all the designers involved. Once the linked files are changed, they are instantly reflected in the model. All the designers can be notified automatically of any changes by one designer. If done in this way, this would dramatically increase the speed and accuracy of the design process involving variegated designers.

2.2.Parameterization for modeling

In the BIM system, the model and design documents are stored in the same database, with all contents parameterized and interrelationships tagged. The two-way correlation and comprehensive change propagation could realize high quality, consistent and reliable information transmission, which would help to provide a digital workflow for designers. Model parameterization could be embodied into the following points:

(1) Parametric model. In the BIM database, designers can define the parameters and the relationships to create a complex structure. Related constraints, which would be maintained automatically by the system, could be set between different parameters to form links.
(2) Structural model. The BIM model contains not only geometrical and physical information, but also information concerning structure. The structural model can be linked to professional software for structural analysis.
(3) Automatic drawing. In contrast with the traditional design, in which the drawings needs to modified manually, the BIM system can deliver the changes to all related drawings accurately and automatically.

2.3. Multi-specialty collaboration

Cooperation and participation between multi-specialty designers is the core concept of collaborative design. Traditional collaboration has the defect of poor efficiency in information transmission and being error prone. This problem solved to some extent by BIM-based collaboration design. Using BIM, the models of each specialty can be shared in real time. BIM would then optimize the teamwork process and should improve design quality. BIM can share the necessary information between every team member as well as carrying out the coordination and audit work needed. As a breakthrough technology, BIM has the potential to change the transmission of information and the design production process in projects.

3. Establishment of the building design collaborative platform

A building design collaborative platform can be used to share models between each designer as shown in Figure 1.

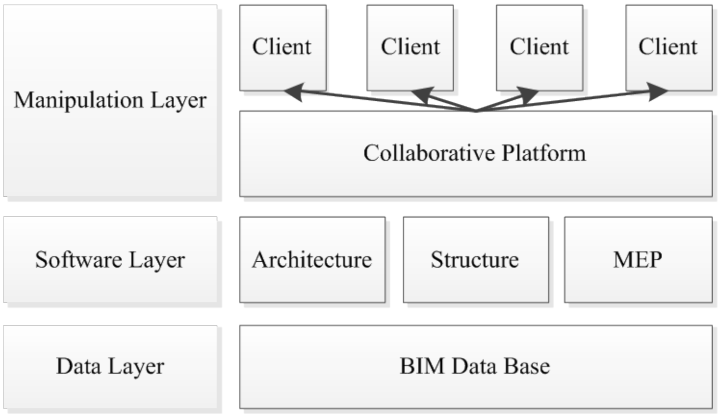


Fig.1. The Collaborative Platform

3.1.Construct of collaborative platform

(1) BIM data base

At the bottom of the platform is the BIM database, which stores building information to be shared by each specialty as the design progresses. The database stores all the information produced in the life cycle of the project. The IFC standard is used to provide a unified format to ensure the validity and integrality of the information during its transmission. Functional interfaces such as input, output and inquiry also need to be developed to provide data support for the storage of information modeling.

(2) BIM software

Professional application software needs to be developed for each specialty to extract the latest information directly from the database. The information should be filtered automatically after extraction from the database. If the raw data in the database were changed, related information would then be changed correspondingly. This should help avoid errors caused by updating information .

(3) Collaborative platform

The building design collaborative platform and associated clients can then be developed based on the software. Clients and designers can use the software to design and edit the information in the model for sharing on the collaborative platform. The platform would clearly define the permissions granted for its use and the administrating permissions for designers.

3.2.Workflow of the collaborative design

With the system, all designers participate in collaborative building design. Figure 2 shows the workflow of the collaborative design. At the concept and scheme design stages, BIM could express the design perfectly, especially in projects of complex shape. Functions such as scheme comparison, performance analysis and feasibility analysis would be used to optimize the design. At the drawing design stage of construction, the BIM-based collaborative platform would provide a means of collaboration between civil and MEP engineers. All members carry out the designs for the same three-dimensional project using a common information model. Designs would be instantly and simultaneously synchronized to the central BIM model. When necessary, related designs would be shared between team members to deal with crossovers. With MEP, after the models for each specialty are completed, the pipeline design would be carried out through the external links. Using BIM, the collaborative platform could detect conflicts following which the two-dimension drawings would be improved according to the appropriate standards, with sketching, animation and virtual construction to guide the construction process.

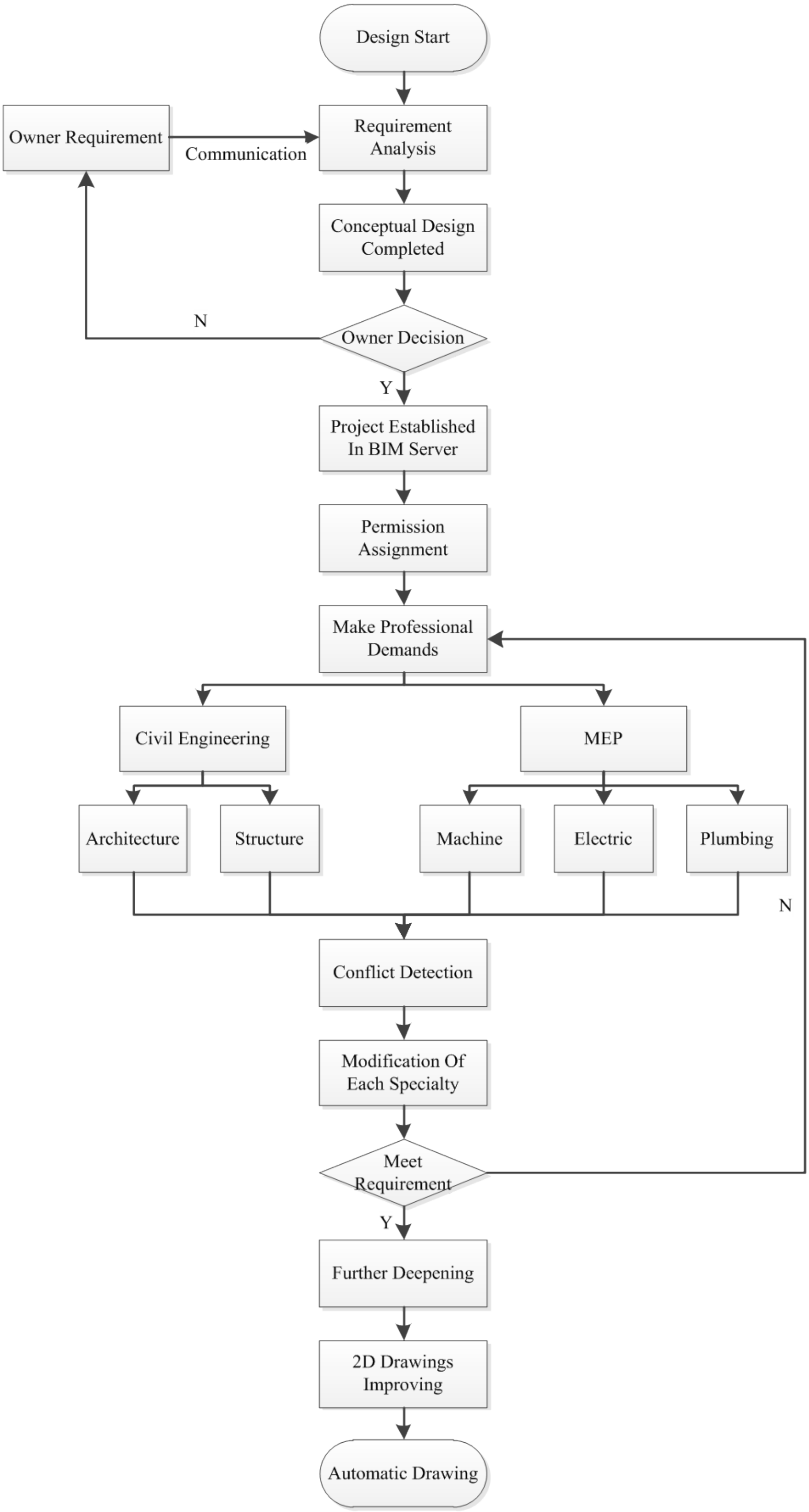


Fig.2. Collaborative Design Workflow

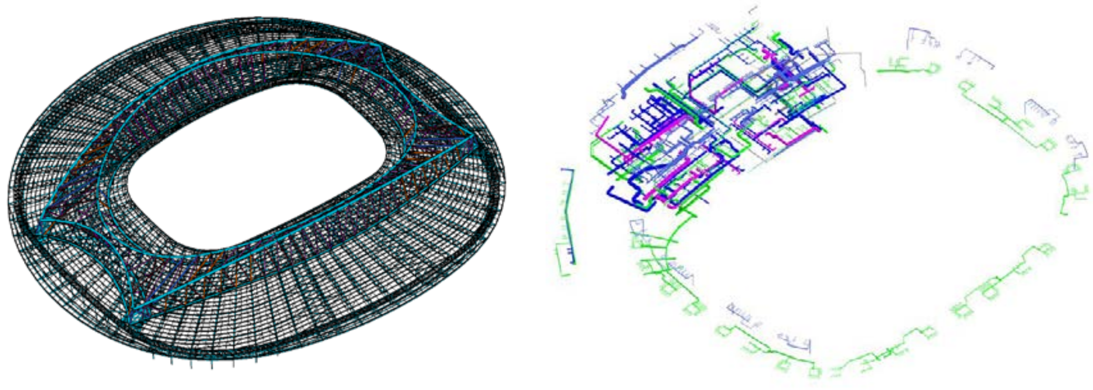
4. Case study

The Algeria BARAKI Stadium is a 40, 000-seat covered stadium whose construction area is 62, 686m^2. As a stadium project, Algeria BARAKI Stadium has complex appearance and large number of pipelines. With mechanical and electrical facilities of a relatively large and complex size, the designers needed to take the opening size of building components into full consideration. The design of the stadium project was therefore a complicated process requiring much collaborative effort. For collaborative design, data sharing and information communication between each discipline is particularly important.

In order to improve the efficiency of the design, particularly that of the MEP, BIM technology was adopted to enable design collaboration between the different design disciplines, i.e. architecture, structure and MEP. With digital building model software, scattered design data and isolated project information was integrated into the platform. This made data sharing and information communication between the different disciplines possible. In this case, the collaborative platform was built using the Autodesk Revit software package. The Autodesk Revit software package contains professional design software such as architecture, structure, mechanical and electrical, and with extensive functions for displaying, analyzing and processing data. On the platform, the designers from each discipline could develop their respective designs. Figure 3 shows the stadium project models built with the Autodesk software.

(a) Overall Model

(b) Architectural Model



(c) Structural Model (d) MEP Model

Fig.3. Project Models

With the advantage of smooth data sharing between the software packages, the variegated disciplines were able to collaborate with each other efficiently. For example, after the electrical engineers from the mechanical discipline completed the composite pipe network layout design of electrical equipment using Revit MEP software, the architect could directly open the design document submitted by electrical engineers, examine the collisions between the two schemes and devise parametric modifications in the 3D environment using the Revit Architecture software without any transformation in the design file format. The Revit Architecture software could accurately obtain the design data and related information from the other design files and maintain associations with them. With any changes to the mechatronic design, the imported revised drawing could update the information and detect collisions and modifications. Figure 4 shows the collision detection and MEP layout.

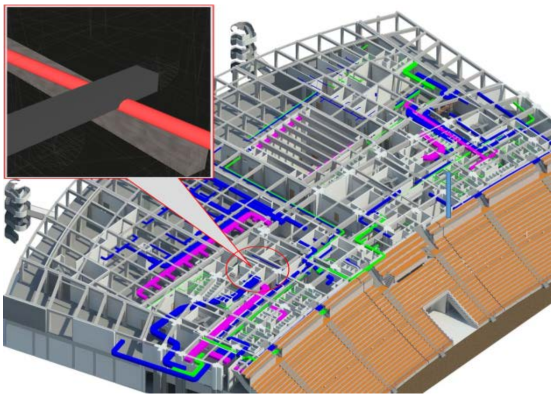


Fig.4. Collision Detection and MEP Layout

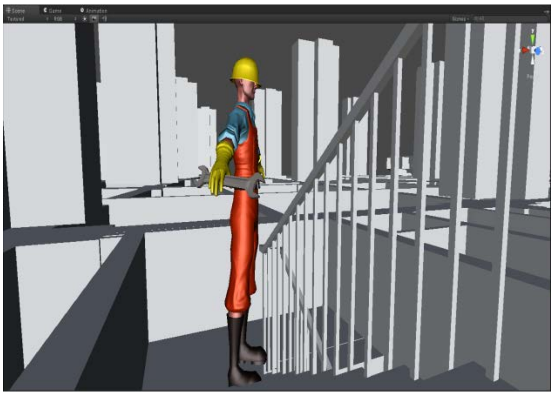


Fig.5. Spatial Analysis

Based on the collaborative platform, this case realized the function of spatial analysis. Using soft collision detection, the Revit Navisworks software was able to check if the design meets the spatial needs, such as in the clear height and distance between components. In the process of designing the mechanical and electrical pipeline, there were many requirements concerning the distance between pipelines. For example, the distance between the feed pipe and drainpipe had to be more than 1.5 meters. By using roaming functions, a personal's virtual roaming in the building helped to check the comfort level of the design, such as whether there would be overcrowded spaces. Figure 5 shows the spatial analysis based on roaming function.

5. Conclusion

This paper reviewed the research status of collaborative design, noting the lack of unified standards and the poor efficiency of traditional two-dimension collaborative design. BIM's application in construction industry and in design was also summarized and found to still have great application opportunities for collaborative design. To utilize the advantages of parametric design and collaboration, a BIM-based building design collaborative platform was constructed and developed for the design workflow and demonstrated in a pilot study. It is believed that a collaborative platform based in

BIM this way would realize the improved cooperation needed when variegated specialty designers are involved and improve the quality and efficiency of the building design process generally...

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