2011 International Conference on Information Management and Engineering (ICIME 2011)
IPCSIT vol. 52 (2012) © (2012) IACSIT Press, Singapore
DOI: 10.7763/IPCSIT.2012.V52.85

Exploring the High-efficiency Clash Detection between Architecture and Structure

Wang Guangbin, Lei Wei [+] and Duan Xuru

School of Economics and Management, Tongji University, Shanghai in P.R.China

Abstract. Building Information Modeling (BIM) has recently attained widespread attention in the AEC/FM (Architectural, Engineering and Construction/ Facilities Management) industry. However, the adoption of BIM is under expectation. Clash detection is critical for adopting BIM, because it is the main part to use for calculating for ROI (return of investment). At the same time, efficiency problem arises in the course of the practical application of clash detection: While existing commercial clash detection software can provides an army of clashes, yet it still need handwork to distinguish design errors from modeling errors. To improve this low-efficiency process, This research provide a revised work process utilizing space naming and coding based on Product Breakdown Structure(PBS), then introduces a case of Shanghai West Railway Station in P.R.China to text this revised process.

Keywords: Adoption of information technology in organizations, Object-oriented enterprise modeling, Building Information Model, model checking; clash detection, return on investment, Product Breakdown Structure, information technology.

1. Introduction

Despite there is doubt that labor productivity in the construction industry has increased or declined during the past three decades, yet this is particularly alarming when compared to the increasing labor productivity in all non-farm industries. The level of productivity improvement is less than one-half that of U.S. non-agricultural productivity gains during the same period [1, 2]. The lack of progress in filed productivity is due to the inherent nature of the construction industry such as [1, 2, and 3]

- Vertically and horizontally fragmented stakeholders
- The principal means of communications in the building process is low efficiency.
- DBB delivery method separates the design and construction phases and leads to overrun and over-budget.
- Lack of interoperability between professionals
- The traditional approach to handling building information and its communication in life cycle management (LCM) [4].

Besides, inappropriate design solutions, construction delays and late delivery and cost overruns are always related to AEC industry.

Building Information Modeling (BIM) is emerging as an innovative way to manage projects. Stanford University Center for Integrated Facilities Engineering (CIFE) figures based on 32 major projects using BIM indicates benefits such as [5]:

- Up to 40% elimination of unbudgeted change.

[+] Corresponding author. Tel.: + 18801962407.
E-mail address: csuleiw@gmail.com.

- Cost estimation accuracy within 3%
- Up to 80% reduction in time taken to generate a cost estimate.
- A savings of up to 10% of the contract value through clash detections.
- Up to 7% reduction in project time.

"BIM" brings with it many advantages for the digital design of buildings. Yet the adoption of BIM in practice has been slower than expectation. According to McGraw-Hill SmartMarket report 2009, BIM, as a new technology, its costs and training issues have been the greatest hurdles on the path to adoption [6]. Currently, the depth of adoption varies significantly between designers, contractors, subcontractors and owners and differences exist between individual disciplines. Not surprisingly, this first phase of BIM adoption has focused on areas of immediate benefit, notably 3D clash detection – checking models from all disciplines (architectural, structural, mechanical, electrical, plumbing, etc.) against each other for interference. This allows designers to create a more efficient design that dramatically reduces collisions, which cause costly changes in the field, wasted spaces in plenums and mechanical rooms.

In a commercial world, although clash detection provides many advantages such as cutting remodeling and design time and eliminating rework, and so on. Yet, as investor, owners and contractors more concern about the ROI (return of investment). Therefore, ROI of clash detection will be the key to promoting BIM, although BIM is not limited to conflict resolution. According to McGraw Hill smart market report then 48% of the respondents are measuring ROI and one third are measuring ROI greater than 100% and several greater than 1000%[7]. PCL construction is measuring up to 500% return of investment with BIM. The major ROI is clash-detections that greatly reduce costly change orders.

BIM savings when measured using real construction phase direct collision detection cost avoidance, savings were computed using planning or value analysis phase cost avoidance.

As evident from Table 2, the BIM return on investment (ROI) for different projects varies from 140% to 39900%. Due to the large data spread, it is hard to conclude a specific range for BIM ROI [8]. The probable reason for this spread is varying scope of BIM in different projects. In some projects, BIM savings were measured using 'real' construction phase 'direct' collision detection cost avoidance, and in other projects, savings were computed using 'planning' or 'value analysis' phase cost avoidance. Also, note that none of these cost figures account for indirect, design, construction or owner administrative or other 'second wave' cost savings that were realized as a result of BIM implementation. Hence the actual BIM ROI can be far greater than reported here. Conservatively, clash detection alone often justifies the expense of modeling.

When conduct clash detections using 3D BIM, another practical problem arises, clash detection for complex projects will yield an army of conflicts. BIM checkers will find it is exhausted to identify relevant clashes [9].

Therefore, to filter out the relevant clashes that cause change orders is challenge. This task contains: (1) find all potential clashed elements; (2) locate their position; (3) complete this process efficiently.

In this paper, we focus on how to improve the efficiency of the clash check, so the structure of the paper is as follows. Chapter 1 introduces the research background and problem description. In chapter 2, a brief review of the BIM and clash detection is given. Then chapter 3 describes the research goal and method. In chapter 4, a desktop audit of the different types of commercial applications for clash detection has been conducted. Based on the previous desktop audit, chapter 5 gives a specific example of revised progress utilizing space naming and coding in Shanghai West Railway Station. The limitation and conclusion is illustrated in the last chapter.

2. Literature Review

2.1. The term BIM

As defined by the National Institute of Building Sciences (United States), BIM is: "A Building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility."[10]

Because all aspects of a project are driven from a single database or related databases, issues of drawing coordination and conflict errors are greatly diminished. Integration of information from multiple disciplines also supports project visualization, simulation, and optimization. The model can even be used to drive computer-controlled fabrication tools, leapfrogging the tedious and error-ridden shop drawing process.

- Parametric Modeling .Parametric modeling is the basis for BIM processes, and in contrast with the polygonal model, the parametric model is data rich. Although a parametric modeling system can create 3D visualizations, the model is not constructed from simple graphical elements. Instead, it is generated from a relational database containing information regarding attributes of a structure's elements and the relationships between them. Fixed or flexible ties can be made between elements allowing the model to either maintain or adjust elements in response to design changes. In addition, the model can be used to generate space calculations, material take-offs, energy efficiency analysis, structural details, and traditional design documents.
- Object-Oriented Modeling. Parametric modeling does not inherently require object-oriented technologies, although in many instances it will. Sometimes referred to as "intelligent objects," object-oriented designs use software objects that encapsulate information concerning each element within the software object rather than the database. Provided they conform to a common specification, objects can be created by third parties, as well as the model designer, and can appropriately interact within the model. The objects communicate with each other and with the model itself and adapt to information received from other objects. In effect, the model is a structure to support communication between "plug-in" objects that digitally simulate characteristics of individual building components that are arranged in a functional design. Despite differences in architecture, both parametric and object oriented software share a functional, rather than graphic, approach to design, as is shown in the following example.

2.2. Clash detection

As now, there isn't existing definition of clash detection. Yet, some scholars have personal opinions. Amine A. Ghanem define clash detection is an iterative process in which all noted project conflicts are addressed and reevaluated until the desired level of coordination has been achieved[11]. Some contend that it is also a process that take all of the separate aspects of the design (e.g. structural, architectural and building services elements) and integrate them into a single 3D model to check for spatial inconsistencies. This would be supported by the DM system which would act as the single mediator for the creation, exchange and revision of project data, and provide a full accountability trail for tracing problems encountered.

Since based on 3D model, clash detection checks models from all disciplines (architectural, structural, mechanical, electrical, plumbing, etc.) against each other for interference. This allows designers to create a more efficient design that dramatically reduces costly changes in the field, wasted spaces in plenums and mechanical rooms. Also, it helps constructors to accurately take-off a building and sequence the construction more easily.

The conflicts are detected in the computer before construction starts, and therefore speed the construction schedule, reduce costs and change orders. The productivity of design and construction are improved accordingly.

Existing clash detection algorithm contains rule-based (such as Solibri Model Checker) and geometry-based (such as Autodesk Navisworks Manager).

Checking for modeling errors is important to ensure the integrity and quality of the model for producing reliable results in other applications in which the model will be used, such as energy analysis, structural analysis, cost estimating, 4D scheduling, multi-disciplinary coordination, and so on. This can be seen as a QA (quality assurance) check for a BIM model. Once all the modeling errors are resolved (this has to be done in the original model authoring application) and relationships between them. Fixed or flexible ties can be made between elements allowing the model to either maintain or adjust elements in response to design changes. In addition, the model can be used to generate space calculations, material take-offs, energy efficiency analysis, structural details, and traditional design documents.

3. Research Methodology

Firstly, with the comprehensive literature review and desktop audit of model checking software, we have concluded three mainstream application's features and the scope for adopting. They are Solibri Model Checker, Autodesk Navisworks Manager and Bentley Interference Manager.

Based on previous work, the clash detection experiment with aim to examine revised measures is conducted. In this experiment, the experimental group was compared with the control group. To exclude personal factor, both experimental group and control group are the same members. The difference between the two groups is that control group still adopts traditional method (just traded colors) and experimental group additionally utilizes space naming and coding based on Product Breakdown Structure.

In the comparative experiment, the members of group are 4 first-year master's students, and the experimental project is Shanghai West Railway Station.

4. Desktop Audit

A desktop audit of the different types of commercial applications that supports collision detection has been conducted. This involved Solibri Model Checker, Navisworks and Bentley interference manager. Products evaluated include detection algorithm, user configure, clash report, import options and other functionalities. The desktop audit provided an overview of the technological capabilities and applications.

Solibri Model Checker as one of the only applications available for model checking first time, one of the few applications that was developed specifically to work with the IFC file format, actually, was developed before BIM was officially introduced in AEC/FM industry. The checking of Solibri is done on the basis of rules grouped into related "rule sets". This can be viewed as "design spell checking". One of most obvious advantages of Solibri Model Checker is to be viewed in the original BIM authoring application, allowing them to be fixed more easily and quickly.

Autodesk Navisworks detects collisions based on geometry. Generating sophisticated renderings is its unique advantage which makes it is different from other similar applications. In addition, the key strength of the Navisworks suite is that it has a complete repertoire of 3D navigation and design review tools, with project scheduling applications to generate time-based simulations. The fatal flaw is it has no intrinsic intelligence about the building model and doesn't support IFC format.

Bentley Interference Manager is an application for the detection, review and management of component interferences in 3D models. It works with designs created in a wide range of commercial applications and provides summary reporting for each interference, as well as methods for tracking and coordinating resolutions for potential design problems

5. Case Study & Result

Shanghai West Railway Station is an integrated transport hub for inter-city rail, urban rail traffic and public transport. To build the GREEN hub of Shanghai West Railway Station, it develops based on the principle of people-oriented, saving space, and reducing transfer distance and facilitating the passage. This high standard of functional localization prompts the owner to adopt BIM, because BIM can greatly enhance the possibility to achieve these targets, not only in green sustainable design analysis and evaluation, but also including the process of fabrication and operation management.

Tab. 1: A desktop audit for clash detection applications

	Solibri Model Checker	**Autodesk Navisworks Manager**	**Bentley Interference Manager**
detection algorithm	Rules-based	Geometry-based	Rules to identify geometric surface
User configure	support	support	support

Clash report	generate	Generating clash report (htm) file	Generating an interference report (RPT) file
Import options	Limited to IFC format only	DWG, DXF, DGN, 3DS, IGES, and so on.	PlansSpace series, MicroStation TriForma, PDS, AutoPlant, and OMNI-Series
The degree of ease of use	Relatively easy	Relatively easy	More complex
Highly-compressed file	SMC file	Navisworks .nwd file	JSM file
Pros	1. Checking for code violations 2. Supporting IFC format	1. imaging 2. publishing takes off	1. effectiveness of detecting spatial interferences 2. perform the analysis interactively without interrupting the design process
Cons	1. Not supporting other commercial applications	1. Has no knowledge of building components as such and only works on the basis of geometry 2. Lack of IFC support	1. Using in 3D CAD models

The clash detection is an important component of BIM, but also a vital tool for meeting green goal of the project. However, the low-efficiency work for identifying design errors hinders clash detection from play a greater role in BIM. Thus, we design this experiment with the project.

On the basis of desktop audit, with consideration that owners have aesthetic requirements, we choose Autodesk Navisworks Manager. As we known, the clashes detected in the application contains modeling errors and design errors which cause change orders. To filter out design clash is time-consuming work. For now, this work can only be done manually one by one, although applications are able to locate collision position and exhibit the name of collision elements (see Fig.1). The purpose of our work is to solve the low-efficiency process, and then we design this experiment. In comparative group, based on Product Breakdown Structure introduced from system engineering, each element in the 3D model is named and coded floor by floor and zone by zone. The following system is an example is used to classify, organize and manage partitions within the BIM model. It' s used to help modeler establish a naming and coding convention of cataloging all partition types in the BIM model (see Fig.2). Partition naming and coding example:

F-4150 A Floor S 2

a) *F-4150 is referred to as the floor elevation*

b) *A is used to represent subdivided zone*

c) *Floor indicates the element(such as wall, column, beam and so on) in the BIM model*

d) *S(South) means the direction of the element*

e) *2 is the sequence number of the element*

Set this rule, the experiment for texting the revised progess is executed. As Autodesk Navisworks Manager can generate a list on the clashes, the task of control group is to fiter the design erros from all of potential collision points. Meanwhile, the amount of time also is recorded. Before comparative group conducted the detection, they were required to name and code every element in accordance with the rules. In this course, clash number and time-consuming also is gauged.

6. Limitation and Conclusion

Some practitioners contend that clash detection by itself is an inefficient process because it is encouraging people to make mistakes with the assumption they will just be caught downstream [12]. From the perspective of lifecycle, clash detection should be through the beginning of design to completion of construction, not just after design before construction. In order to improve the present low-efficiency situation, our study is limited to how to improve clash detection after design phase. Another limitation to note is that our experiment is only limited to architecture and structure. As we known, if considered the MEP, the process is more complex [13]. Yet, according to our experiment, once a proper rule was established, this revised process will also be helpful.

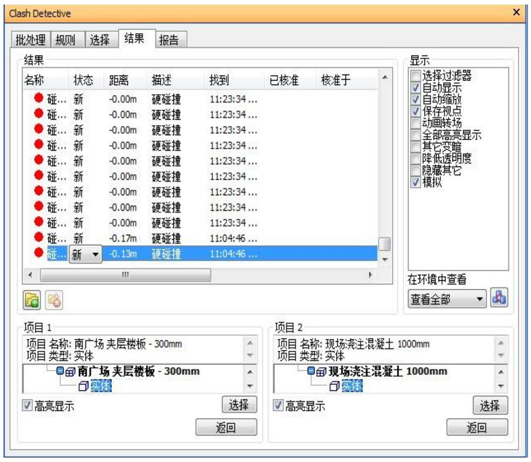

Fig. 1: The of traditional way of collision verification

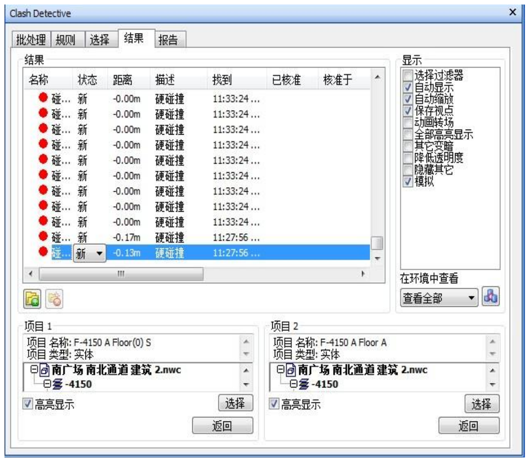

Fig. 2: Utilizes space naming and coding based on Target Decomposition

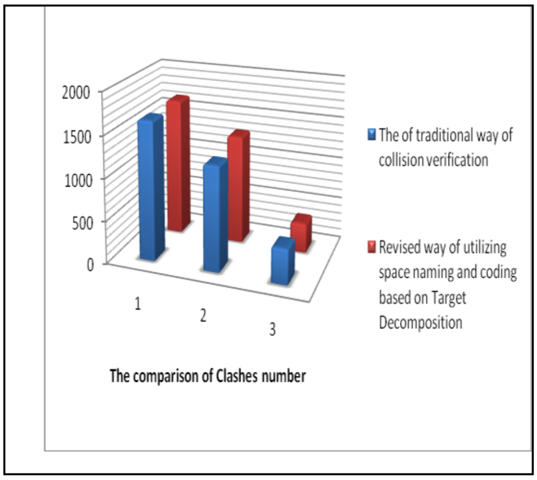

Fig. 3: The comparison of clashes number

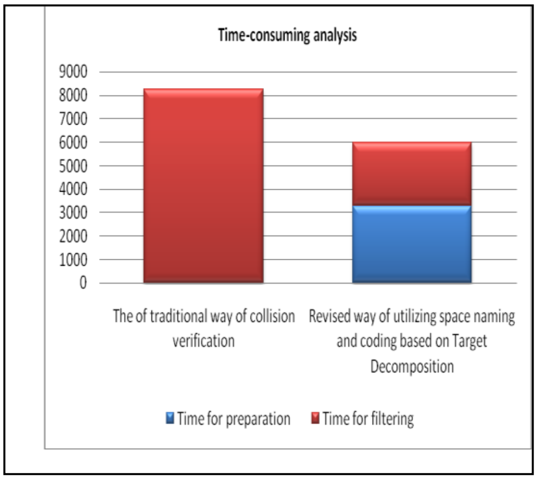

Fig. 4: Time-consuming analysis

The data collected in this experiment indicates that revised process of utilizing space naming and coding based on target decomposition is better than the traditional way of collision verification both in term of clashes number and time-consuming. In the comparison of clashes number, the design errors detected by revised way of utilizing space naming and coding is 15.5% less than the traditional way(see Fig.3); In time-consuming analysis, even though it takes some time to do preparation work, yet the sum time of revised way is 27.6% less than the traditional way finally(see Fig.4).

On the whole, the revised way of utilizing space naming and coding is able to improve the efficiency of clash detection between architecture and structure.

7. Reference

[1] Construction Productivity. HASKELL White papers.

[2] Paul Teicholz, Labor Productivity Declines in the construction Industry: Causes and Remedies. AECbytes Viewpoint #4.

[3] Eastman, C., Fischer, D., Gilles, L., Lividini, J. Stoker, D., Yessios, C., 1974, An Outline of the Building Description System, Computer-Aided Design, volume 8 issue 1, pp. 17-26

[4] Shaibu B.Garba and Mohanmad A. Hassanain 2004, "A review of object oriented CAD potential for Building Information Modeling and Life Cycle Management."

[5] Ju Gao, Martin Fischer, 2008, "Framework & Case studies comparing implementation & impacts of 3D/4D modeling across projects."

[6] Mcgraw Hill Smartmatket report,2007, 2008,2009

[7] Building information modeling project decision support framework.

[8] http://www.bimoutsourcing.com/bim-return-on-investment-(ROI).htm

[9] Howard W. Ashcraft, Jr. Esquire ,Implementi BIM: A report from the field on issues and strategies. The 47th Annual Meeting of Invited Attorneys

[10] National Institute of Building Sciences. Whole Building Design Guide. Available at www.wbdg.org.

[11] Amine A. Ghanem, "Building Information Modeling Applied on a Major CSU Capital Project: A Success Story"

[12] Thomas M. Korman,2008,"Using Building Information Modeling to improve the Mechanical, Electrical, and Plumbing Coordination Process for Buildings" 2008 AEI:Buildiing Integration Solutions