Development of BIM Model Fitness Review System for Modelling Quality Control

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ABSTRACT

The increasing focus on Building Information Modeling (BIM) enables massive utilization of model checking software. Several software applications, such as *Solibri* and *Navisworks*, are applicable with a large list of powerful functions. Existing computer-supported model checking applications are mainly concentrated on verifying various codes and constructability based on as-designed 3D model which derived from 3D design results or 2D drawings. The effectiveness of these kinds of model check largely relies on the accuracy of as-designed 3D model itself. Unfortunately, rare research is implemented to review as-designed 3D model and assure information accuracy. This paper develops a systematic approach for BIM model fitness review through predefined standards. Firstly, the paper starts by discussing the need for automated BIM model review and analysing the limitations of existing model checking efforts in this regard. Then, an overview of the proposed BIM Model Fitness Review System (BIM^{2}FRS) is provided. Thirdly, the paper presents a case study to validate the BIM^{2}FRS. The result shows that: (1) the system can efficiently assess BIM model fitness and support BIM model management; (2) The development of the ABIM^{2}R system is still very young; and (3) only limited types of model fitness review are presented.

INTRODUCTION

The increasing focus on Building Information Modeling (BIM) enables massive utilization of model checking software. Several software applications, such as *Solibri* and *Navisworks*, are applicable with a large list of powerful functions. The effectiveness of these kinds of model check largely relies on the accuracy of as-designed 3D model itself. Unfortunately, rare research is implemented to review as-designed 3D model and assure information accuracy. However, existing research and computer-supported model checking applications are mainly concentrated on automate building-code checking so that design schemes can comply with lots of codes such as fire safety, structure and sustainability. (Shih et al. 2013) investigated to translate building codes into XML-based tables which provided a foundation for the development of code-checking systems using BIM to assess compliance. (Tan et al. 2010) presented a new integrated approach to automated code compliance checking for building envelope design based on simulation results and building codes. In this approach, building codes and simulation results were seamlessly linked with the compliance checking software. (Balaban et al. 2012) developed an automated code compliance checking system for checking building models against some parts of the Turkish Fire Codes. (Hjelseth and Nisbet 2010) presented an overview of concepts for model checking. Four different concepts were identified: Validating systems, Guiding systems, Adaptive systems and Content based checking. By using an ontological approach they proposed a four level taxonomy of model checking: Intention, Result, Rule set and Type of products. Model checking should be regarded as a knowledge system for support of the design process. (Jeong and Lee 2009) discussed how to automatically check codes for anti-disaster and egress based on Korea building codes. (Nawari 2012) had proposed a new framework for automated code conformance systems for the structural design realm. (Martins and Monteiro 2013) presented a review of the core principles behind BIM-based automated code-checking, and discussed the role of the IFC model as a viable format for the exchange of data in a code-checking system, as well as current international automated code-checking initiatives. (Melzner et al. 2013) had developed a customizable automatic safety rule-checking platform for building information models. The applied rule-based checking algorithms were designed to be add-ons to existing BIM software and could check models for safety hazards early in the design and planning process. (Greenwood et al. 2010) and (Nawari 2012) had reviewed previous research related to automated code checking, which included evaluating and reviewing the functional capabilities of both the technology and structure of current BIM model checking systems.

Existing code checking methods are mainly rule-based checking systems (utilizing if-then-else logic statements) that assess building designs based on a set of well-defined criteria. Some codes such as laws and regulations are normally complex to interpret. (Salama and El-Gohary 2011) explored a new approach to automated regulatory compliance checking. They applied theoretical and computational developments in the fields of deontology, deontic logic, and Natural Language Processing (NLP) to the problem of regulatory compliance checking in construction. (Pauwels et al. 2011) developed a semantic rule checking environment for building design and construction. (Yurchyshyna et al. 2007) concluded with a preliminary conceptual framework based on Semantic

Web technologies modeling the conformance checking problem, as well as the technical solutions for its implementation.

Whether it is possible to develop a valid and reliable BIM-based model check system applicable to rule sources (laws, codes, regulations and standards) depends on one key hypothesis: the information in as-designed BIM models is accurate and normative. Unfortunately, rare research is implemented to review as-designed 3D model and assure information accuracy. This paper develops a systematic approach for BIM model fitness review through predefined standards. Firstly, the paper starts by discussing the need for automated BIM model review and analysing the limitations of existing model checking efforts in this regard. Then, an overview of the proposed BIM Model Fitness Review System (BIM^{2}FRS) is provided. Thirdly, the paper presents a case study to validate the BIM^{2}FRS. Finally, some lessons learned and issues are highlighted that help direct future research and implementation.

THE PROPOSED BIM MODEL FITNESS REVIEW SYSTEM (BIM^{2}FRS)

This section describes a proposed BIM^{2}FRS framework (as shown in Figure 1) which consists of BIM execution process and BIM^{2}FRS in the overall project delivery process. Two typical processes of BIM model creation are identified in Figure 1: process A and process B. Table 1 shows the detailed checklist of BIM^{2}FRS and Table 2 demonstrates the grades of BIM model fitness.

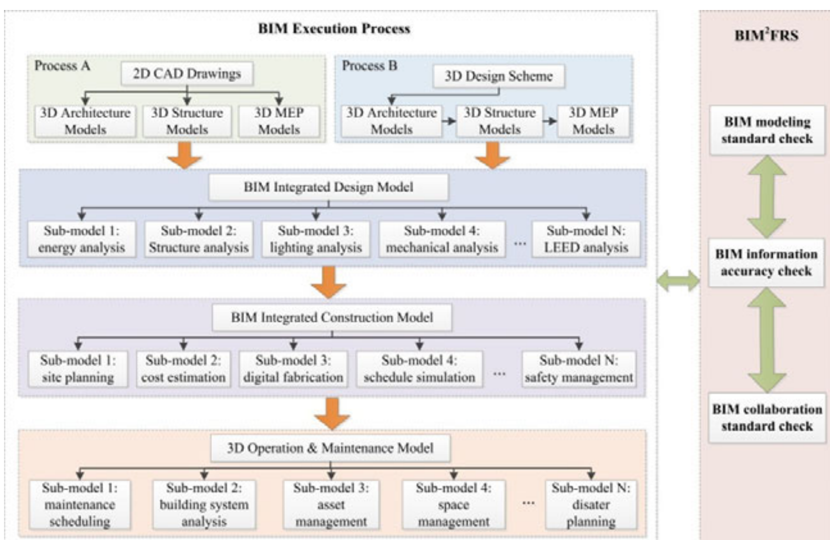


Figure 1. The proposed BIM Model Fitness Review System

CASE STUDY

Project Z15 was one of the tallest buildings in China. The height was 528m, 108 floors on the ground and 7 floors underground. The function of the building was mainly for offices. In addition, the top area was equipped with business club and city sightseeing hall. Considering the need to host heaps of equipment and complex systems, it was difficult to plan the building systems using the traditional 2D CAD. BIM was determined to be used in order to eliminate spatial and functional interferences and improve building performance.

Table 1. Detailed checklist of BIM^{2}FRS

	Categories (points)	Subcategories (points)
BIM Model Review System (0-100)	BIM modeling standard check (0-40)	BIM modeling software version check (0-2)
		BIM files format, structure and size check (0-3)
		BIM model structure check (0-3)
		BIM naming rules check (0-3)
		BIM element level of detail check (0-10)
		BIM model level of development check (0-10)
		BIM model coordinate system check (0-3)
		BIM model unit check (0-3)
		BIM model color coding standard check (0-3)
	BIM information accuracy check (0-40)	Location (0-10)
		Geometric dimensioning (0-10)
		Annotation (0-10)
		Modeling technique (0-10)
	BIM collaboration standard check (0-20)	Working set (0-10)
		Link & share (0-10)

Table 2. The grades of BIM model fitness

Status	Score	symbol
Excellent	90-100	
Good	80-90	
Average	70-80	
Poor	60-70	
unacceptable	0-60	

BIM modeling standard check. This section gave detailed evidences about BIM model fitness review from the angle of BIM modeling standard check.

BIM modeling software version check. BIM modelling software version met the requirements, using the Revit2013, other software such as Rhino and Tekla could be also integrated with Revit (as shown in Figure 2).

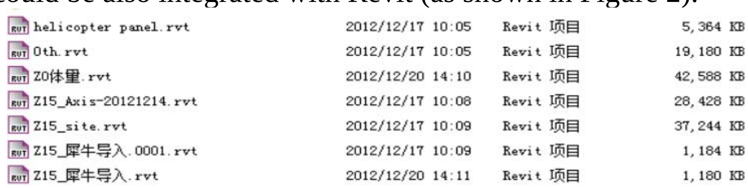


Figure 2. BIM modeling software version check

BIM files format, structure and size check.

(1) BIM files format met the requirement and submit the original format such as *rvt* and *nwd* (as shown in Figure 3).

Figure 3. BIM files format check

(2) The sizes of BIM files were between 20Mb and 50Mb, and no files were submitted exceed 200Mb (as shown in Figure 4). However, the files still had

lots of space to further compress and clean up. Table 3 showed the result after further compressing and cleaning by us which reduce 70% of the original files size.

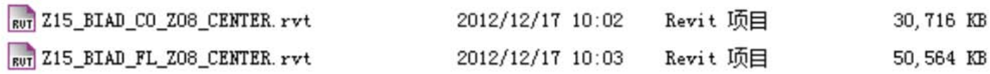
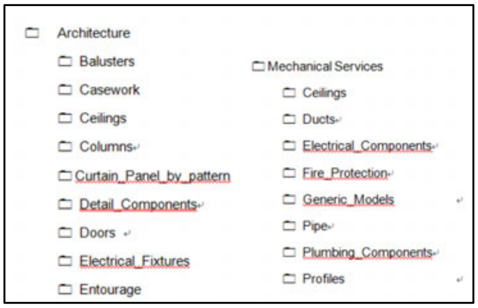


Figure 4. BIM files size check

Table 3. The comparision among original size, size after compressing and size after cleaning

File Name	File Size Original size (MB)	Size after compressing (MB)	Size after cleaning (MB)
Z15_BIAD_FL_M01_CENTER.rvt	22.556	16.736	4.820
Z15_BIAD_CO_M01_CENTER.rvt	26.812	18.124	6.952
Z15_BIAD_FL_M02_CENTER.rvt	23.836	17.064	5.164
Z15_BIAD_CO_M02_CENTER.rvt	24.444	18.732	7.224
Z15_BIAD_FL_M03_CENTER.rvt	24.040	17.384	5.708
Z15_BIAD_CO_M03_CENTER.rvt	25.472	19.396	7.840
Z15_BIAD_FL_M04_CENTER.rvt	21.236	15.304	3.324
Z15_BIAD_CO_M04_CENTER.rvt	21.900	16.252	4.956
Z15_BIAD_FL_M05_CENTER.rvt	18.116	16.312	3.520
Z15_BIAD_CO_M05_CENTER.rvt	23.068	16.300	3.764
Z15_BIAD_FL_M06_CENTER.rvt	26.432	23.868	3.212
Z15_BIAD_CO_M06_CENTER.rvt	31.220	21.252	3.824
Z15_BIAD_FL_M07_CENTER.rvt	18.392	18.056	6.220
Z15_BIAD_CO_M07_CENTER.rvt	17.960	16.352	4.672
Z15_BIAD_FL_M08_CENTER.rvt	27.240	21.300	9.420
Z15_BIAD_CO_M08_CENTER.rvt	38.444	28.580	16.400
Z15_BIAD_FL_R01_CENTER.rvt	18.548	15.888	3.068
Z15_BIAD_CO_ R01_CENTER.rvt	24.740	18.248	6.376
Z15_BIAD_FL_ R 02_CENTER.rvt	18.616	16.176	3.412
Z15_BIAD_CO_ R 02_CENTER.rvt	24.168	18.612	7.076
Z15_BIAD_FL_ R 03_CENTER.rvt	17.136	14.776	2.256
Z15_BIAD_CO_ R 03_CENTER.rvt	23.018	17.528	6.036
Z15_BIAD_FL_ R 04_CENTER.rvt	28.056	25.628	12.728
Z15_BIAD_CO_ R 04_CENTER.rvt	21.080	15.856	4.808
Z15_BIAD_FL_ R 05_CENTER.rvt	22.680	21.224	2.056
Z15_BIAD_CO_ R 05_CENTER.rvt	17.612	16.520	3.572
Z15_BIAD_FL_ R 06_CENTER.rvt	29.632	28.380	2.556
Z15_BIAD_CO_ R 06_CENTER.rvt	39.296	21.580	3.752
Z15_BIAD_FL_ R 07_CENTER.rvt	14.068	14.000	1.548
Z15_BIAD_CO_ R 07_CENTER.rvt	17.972	16.940	5.028
Z15_BIAD_FL_ R 08_CENTER.rvt	23.136	20.592	8.220
Z15_BIAD_CO_ R 08_CENTER.rvt	26.980	22.688	10.204
Z15_BIAD_FL_Z01_CENTER.rvt	50.560	23.660	12.140
Z15_BIAD_CO_ Z 01_CENTER.rvt	56.120	30.064	18.276
Z15_BIAD_FL_ Z 02_CENTER.rvt	33.616	19.864	7.932
Z15_BIAD_CO_ Z 02_CENTER.rvt	44.624	25.824	14.372
Z15_BIAD_FL_ Z 03_CENTER.rvt	46.852	38.528	27.184
Z15_BIAD_CO_ Z 03_CENTER.rvt	55.808	31.392	19.932
Z15_BIAD_FL_ Z 04_CENTER.rvt	44.312	36.544	25.120
Z15_BIAD_CO_ Z 04_CENTER.rvt	40.952	22.088	10.664
Z15_BIAD_FL_ Z 05_CENTER.rvt	74.620	48.220	29.256
Z15_BIAD_CO_ Z 05_CENTER.rvt	36.436	27.760	14.848
Z15_BIAD_FL_ Z 06_CENTER.rvt	83.712	21.064	12.180
Z15_BIAD_CO_ Z 06_CENTER.rvt	17.780	12.780	12.524
Z15_BIAD_FL_ Z 07_CENTER.rvt	27.580	21.560	9.736
Z15_BIAD_CO_ Z 07_CENTER.rvt	32.836	23.948	12.500
Z15_BIAD_FL_ Z 08_CENTER.rvt	50.564	42.620	30.396
Z15_BIAD_CO_ Z 08_CENTER.rvt	30.716	20.708	8.988
Total	1484.994	1052.272	445.764

(3) The structure of core folders, project folders and library folders met the requirement of the guideline (as shown in Figure 5).



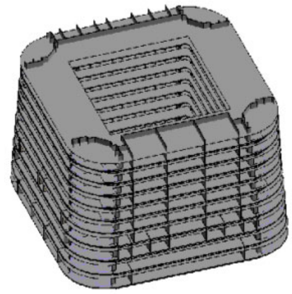


Figure 5. BIM files structure check **Figure 6. BIM model structure check**

BIM model structure check. BIM Model was reasonably divided into nine zones (as shown in Figure 6). According to the functions, each zone could be further divided into core tube, interlayer and refuge storey. Building components were separated according to the floor and ceiling so that to guarantee the controllability of model file size, and not affect the integrity of the model.

BIM naming rules check. Several files naming, such as Z15_Axis-20121214.rvt (as shown in Figure 7), were inconsistence with the requirement. The correct name should be Z15_Axi.rvt.

Figure 7. BIM naming rules check **Figure 8. BIM element level of detail Check**

BIM element level of detail check. Component geometry information including shape, size, etc., was all in accordance with the requirement of the preliminary design stage (as shown in Figure 8).

BIM information accuracy check. Table 4 showed the alert items in detail, and table 5 showed the inconsistence between 2D drawings and 3D BIM model.

Table 4. Alert items list

No.	Alert items	Quantity
1	Location	5
2	Geometric dimensioning	10
3	Annotation	4
4	Modeling technique	26

Table 5. Inconsistence between 2D drawings and 3D BIM model

No.	Inconsistence items	Quantity
1	Architecture	35
2	Structure	8
3	MEP	56

BIM collaboration standard check. Table 6 showed the results after BIM collaboration standard checking. There are about 24 issues occurred in putting wrong building system into incorrect working set.

Table 6. Working set issues

No.	File Name	Working Set Name	Issues
1	Z15_BIAD_C0_M02_CENTER	Working Set 1	Putting wall system into working set 1
2	Z15_BIAD_FL_M02_CENTER	Working Set 1	Putting partition system into working set 1
3	Z15_BIAD_CO_M05_CENTER	Working Set 1	Putting structural beam system into working set 1
4	Z15_BIAD_CO_M07_CENTER	Working Set 1	Putting structural beam system into working set 1
5	Z15_BIAD_CO_M08_CENTER	Working Set 1	Putting door and window system into working set 1
6	Z15_BIAD_FL_M08_CENTER	Working Set 1	Putting door and window system into working set 1
7	Z15_BIAD_CO_R01_CENTER	Working Set 1	Putting door and window system into working set 1
8	Z15_BIAD_FL_R02_CENTER	Working Set 1	Putting partition system into working set 1
9	Z15_BIAD_CO_R05_CENTER	Working Set 1	Putting structural beam system into working set 1
10	Z15_BIAD_CO_R06_CENTER	Working Set 1	Putting structural beam system into working set 1
11	Z15_BIAD_CO_R07_CENTER	Working Set 1	Putting structural beam system into working set 1
12	Z15_BIAD_CO_R08_CENTER	Working Set 1	Putting door and window system into working set 1
13	Z15_BIAD_FL_R08_CENTER	Working Set 1	Putting door and window system into working set 1
14	Z15_BIAD_FL_Z01_CENTER	Working Set 1	Putting partition system into working set 1
15	Z15_BIAD_FL_Z02_CENTER	Working Set 1	Putting partition system and door and window system into working set 1
16	Z15_BIAD_CO_Z03_CENTER	Working Set 1	Putting partition system and door and window system into working set 1
17	Z15_BIAD_FL_Z04_CENTER	Working Set 1	Putting partition system into working set 1
18	Z15_BIAD_CO_Z05_CENTER	Working Set 1	Putting structural beam system into working set 1
19	Z15_BIAD_FL_Z06_CENTER	Working Set 1	Putting structural steel beam system into working set 1
20	Z15_BIAD_CO_Z07_CENTER	Working Set 1	Putting fireproof door system into working set 1
21	Z15_BIAD_FL_Z07_CENTER	Working Set 1	Putting celling system into working set 1
22	Z15_BIAD_FL_Z08_CENTER	Working Set 1	Putting structural column system into working set 1
23	Z15_BIAD_CO_ZB_CENTER	Working Set 1	Putting partition system and door and window system into working set 1
24	Z15_BIAD_FL_ZB_CENTER	Working Set 1	Putting partition system, floor system and door and window system into working set 1

CONCLUSION

This paper develops a systematic approach for BIM model fitness review through predefined standards. Firstly, the paper starts by discussing the need for automated BIM model review and analysing the limitations of existing model checking efforts in this regard. Then, an overview of the proposed BIM^{2}FRS is provided. Thirdly, the paper presents a case study to validate the BIM^{2}FRS. The result of the case study shows that: (1) the system can efficiently assess BIM model fitness and support BIM model management; (2) The development of the ABIM^{2}R system is still very young; and (3) only limited types of model fitness review are presented.

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