



Creative Construction Conference 2016

A BIM Based Approach for Quality Supervision of Construction Projects

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Abstract

Quality supervision is an important means to ensure the quality of construction projects. Despite the variation in relevant standards of different countries, the core of supervision is to inspect and control each major construction procedure. Up to now, some application software for quality supervision have been used in engineering. However, too many inspection items specified by the relevant standards, lack of experience of inspection personnel, and the process of entering the data in the original record into computers have led to the inefficiency of the inspection work and data falsification, which buries the seeds of risk for construction quality.

In order to solve the problems, a BIM based approach to improving the quality supervision of construction projects is proposed. Firstly, the requirements analysis of the system is carried out. Then, the IFC (Industry Foundation Classes) standard for BIM (Building Information Modeling) data is analyzed and an IFC based information model for quality supervision is established. Next, an algorithm is established to automatically generate inspection points based on BIM and the related standards. Finally, a prototype system using BIMserver.org as the platform is developed, which facilitates inspectors to check inspection points according to standards, to get smart tips when inputting data on mobile terminal at the construction sites and to automatically generate standard documents without second input. Compared with the traditional ones, the approach provides a great improvement for quality supervision of construction projects.

Keywords: building information modeling, construction, quality supervision, standards.

1. Introduction

The construction quality relates to the public safety and interests. It is mainly determined by construction process. Therefore, according to the relevant standards, the construction process is normally strictly regulated, which is called quality supervision. Despite the variation in the relevant standards of different countries, the core of supervision is to inspect and control each construction procedure. However, too many inspection items specified by the relevant standards, lack of experience of inspectors, and the process of inputting the data in the original record into computers have led to the inefficiency of the inspection work and data falsification, which buries the seeds of risk for construction quality.

Building Information modeling (BIM) [1] provides a new information management means. BIM models with attributive information can support the information sharing and collaborative work among the involved users, which makes it possible to improve the quality supervision. Park et al. put forward a conceptual framework using BIM, augmented reality and ontology-based data collection template for proactive construction defect management [2]. Kwon et al. proposed a defect management system for reinforced concrete work to avoid recurring defects by utilizing BIM, image-matching and augmented reality [3]. Tsai et al. proposed an approach for construction inspection based on BIM to improve the efficiency of inspection and reduce the burden of the inspectors [4]. But overall, the current research rarely take into account the related standards.

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In order to solve the problems, a BIM based approach to improving quality supervision of construction projects, which uses a quality supervision system based on BIM to be developed, is proposed. Firstly, the requirements analysis of the system is carried out. Then an information model for quality supervision based on IFC [5] data is established for the development of the system. Next, a key algorithm to be used in the system is established to automatically generate inspection points of quality inspection based on BIM and the related standards. Finally, a prototype system is developed by using BIMserver.org as the platform of BIM data and presented to illustrate the effects of the approach.

2. Requirements Analysis

According to the national standards in China, in order to ensure the construction quality, every major working procedure needs to be inspected effectively. Contractors will conduct the self-inspection first when a major working procedure is completed. Then supervisors from a contracted supervision company will confirm the inspection result on behalf of the society before the next procedure can be continued. Managers from a developer such as a real estate company may inquire the inspection state and result whenever they want. All the relevant inspection items, inspection methods and required quantity of inspection points are described in the standards [6].

In order to solve the problems described in Section 1, the quality supervision system based on BIM is designed. The users of the system include the relevant inspectors such as contractors, supervisors and managers. The key functional requirements have been established based on the standards and the result of investigation on supervision process, as shown in Table 1.

Table 1. Key functional requirements of quality supervision system based on BIM.

No.	Function name	Function description
1	Import, browse and operate 3D model	Import IFC data, view model and components hierarchically, operate model with zoom, translation and rotation to help inspector quickly get the inspection target.
2	Automatically generate inspection lots, items and points	Establish an algorithm to generate inspection lots, items and points automatically which can help inspectors establish inspection plan before construction and carry it out orderly and normally at the construction site.
3	Fill out customized forms	Complete supervision successively by filling out the customized forms with smart tips.
4	Automatically generate standard documents	The form completed at the construction site can be automatically converted into standard document without second input.
5	View the state and results of supervision process	View and monitor the supervision data transmitted from the construction site and count up the status and result of the whole supervision process.

3. Establishing information model and algorithm

3.1. Information model of quality supervision based on BIM and related standards

Based on the key functional requirements as stated in Section 2, an information model was derived for the development of the system by analyzing the relevant information, as shown in Figure 1.

It is obvious that a project is divided into many sub-projects of different level such as the part projects, item projects and inspection lots. Inspection points are randomly sampled from inspection lots and contain a series of inspection items to be inspected according to the standards. On the other side, BIM models with many relevant elements that are defined by space relationship such as floor and axis, elements type such as column and beam, and elements property such as material and area are assumed to be in the format of IFC, which is an international standard of BIM data. Inspection points and the elements are connected as inspection object to be applied to the quality supervision of construction process.

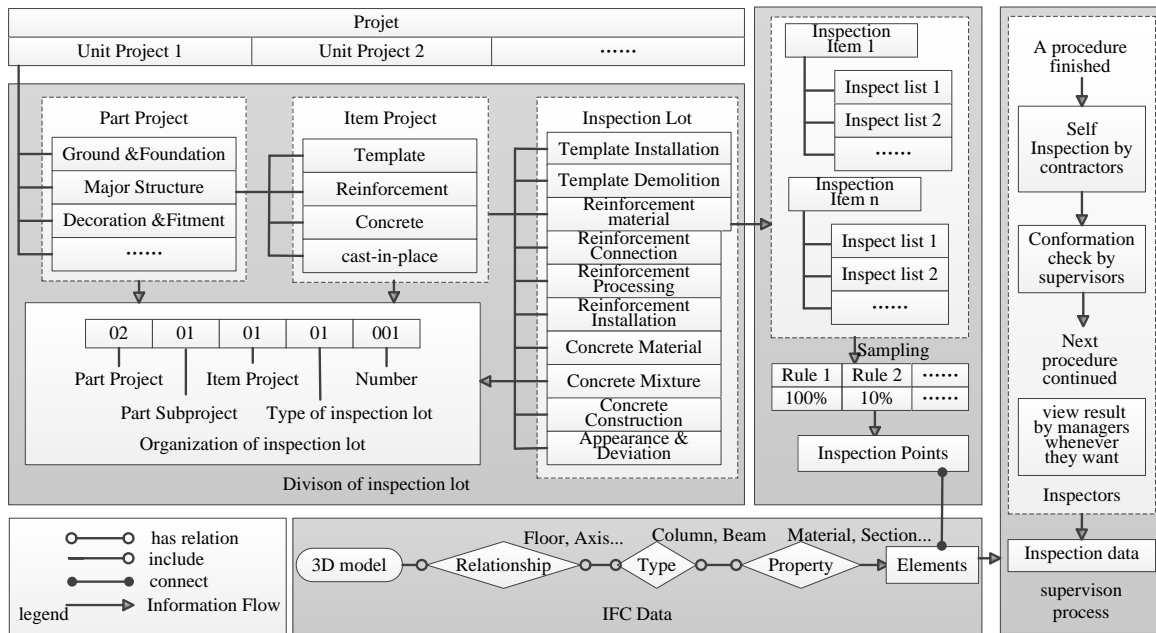


Figure 1. Information model for quality supervision based on BIM and related standards.

3.2. Algorithm for automatically generating inspection items and points based on BIM and related standards

IFC data includes not only the entity such as column, beam, plate, etc., but also the abstract concepts such as floor, axis, etc. Thus, based on the division rules of inspection lots, definition of inspection items and sampling rules of inspection points in the related standards, an algorithm is established for automatically generating inspection lots, items, and points based on BIM, as shown in Figure 2.

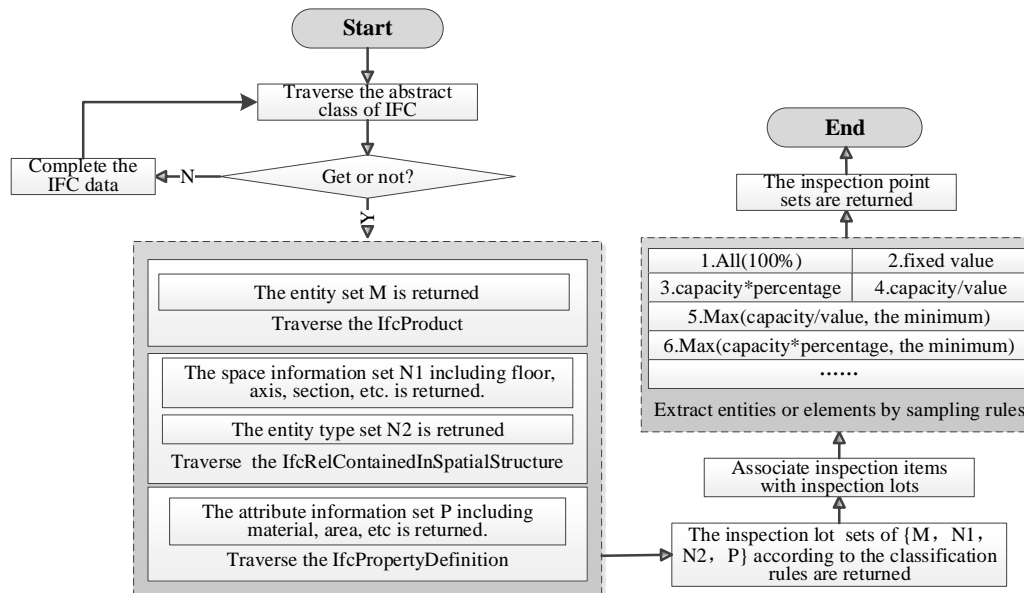


Figure 2. Algorithm for automatically generating inspection lots, items and points based on BIM and the related standards.

Firstly, IFC data are traversed to get the information of abstract class including Ifc product, IfcRel contained in spatial structure and Ifc property definition. Then, the set of entity, the space relationship, the entity type, and the attributive information are thus returned separately. Next, inspection lots are returned as $\{M, N1, N2, P\}$ according to the classification rules and inspection items are associated with the results. Finally, inspection points are returned after sampling from inspection lots in accordance with each inspection item. The generated inspection lots, items and points will be stored in the database and used to support inspectors to view the inspection plan and get smart tips with mobile device.

4. Implementation of the approach based on BIMserver.org

The quality supervision system based on BIM has been developed to implement the key requirements. The system adopts B/S (Browser/Server) [7] architecture and can run on both a desktop browser and a mobile browser. BIMserver.org [8] was chosen to be the platform to manage the BIM data so as to greatly reduce the initial work of the implementation. Spring MVC [9] was used as the open source framework. MySQL [10] was chosen to be the database. After the completion of the system, a preliminary trial use was carried out.

4.1. Architecture design

BIMserver.org is an open source platform proposed by TNO of Netherlands. It supports the need to view and manage BIM data with IFC format [11]. The architecture of the system that uses the BIMserver.org is shown in Figure 3, in which the useful services of the BIMserver.org are called in the Spring MVC framework.

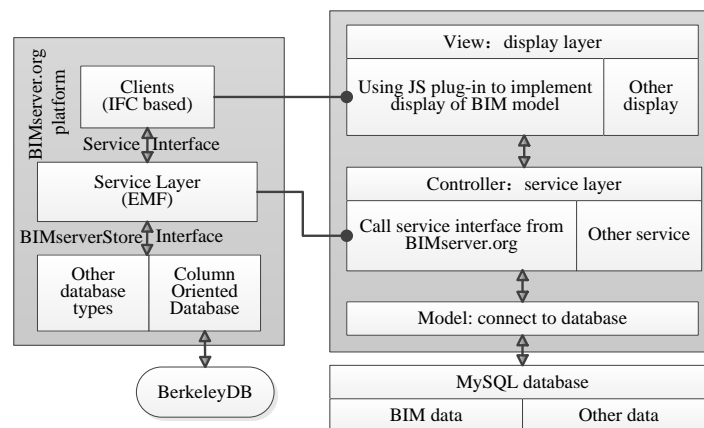


Figure 3. Architecture of quality supervision system based on BIM

4.2. Application scenarios demonstration

The system contains four categories of commands, i.e. project management, plan management, process management and result management. The typical application scenarios are explained briefly as follows.

By using the commands in the category of project management, a user from the contractor creates a project first, then uploads the relevant model file of IFC 2x3 [12, 13] or IFC 4 [14]. Then, the IFC files are automatically parsed and the 3D model is displayed in the browser. Users can view the project, model information, and operate the models by zooming, panning and rotating.

The commands in the category of plan management are used to automatically generate inspection lots, items and points based on the relevant standards. The inspection lots and items are organized as a tree-structure for a better index, and the inspection points are displayed as spheres on the model. For instance, the inspection lot of cast-in-place structure contains two principal and two general inspection items. Taking the first principal item as an example, which means, "the appearance has no serious defects", should be inspected on all components. Considering the construction sequence and inspection convenience, all columns and walls of the first floor should be inspected first. That is how inspection lots and points come from [15]. Figure 4 shows the main interface of the system in which the generation of inspection points of first inspection lot's first item is displayed. Compared with the traditional method of quality supervision, the generation of inspection lots, items and points automatically before construction avoids omission and negligence at the construction site. Besides, it is much easier for new inspectors to learn the current situation when some construction personnel changes.

By using the commands in the category of process management, inspectors click the generated inspection lots, items and points with mobile device to finish the self-inspection, conformation and rectification. They get smart tips and fill out customized forms for each inspection item specified by standards. The item can be basically divided into qualitative item and quantitative item. The former requires qualitative judgment or uploading documents. The latter requires inputting data. Figure 5 shows an example of filling out a self-inspection form corresponding to 5 columns and the qualitative item of "Appearance has no serious defects". After completing the judgment, uploading or inputting, the inspection result will be generated automatically and displayed on the model with different color. Compared with the traditional supervision process, without having to carry a lot of printed standards, inspectors can get smart tips of inspection lots, items, points and customized forms from the system

with mobile device, so they can quickly complete every procedure and upload the inspection data to the server to automatically generate standard documents for a better management without second input. The system makes it possible to simplify and standardize the inspection process, avoid the disorder of data, and reduce the possibility of falsification without second input.

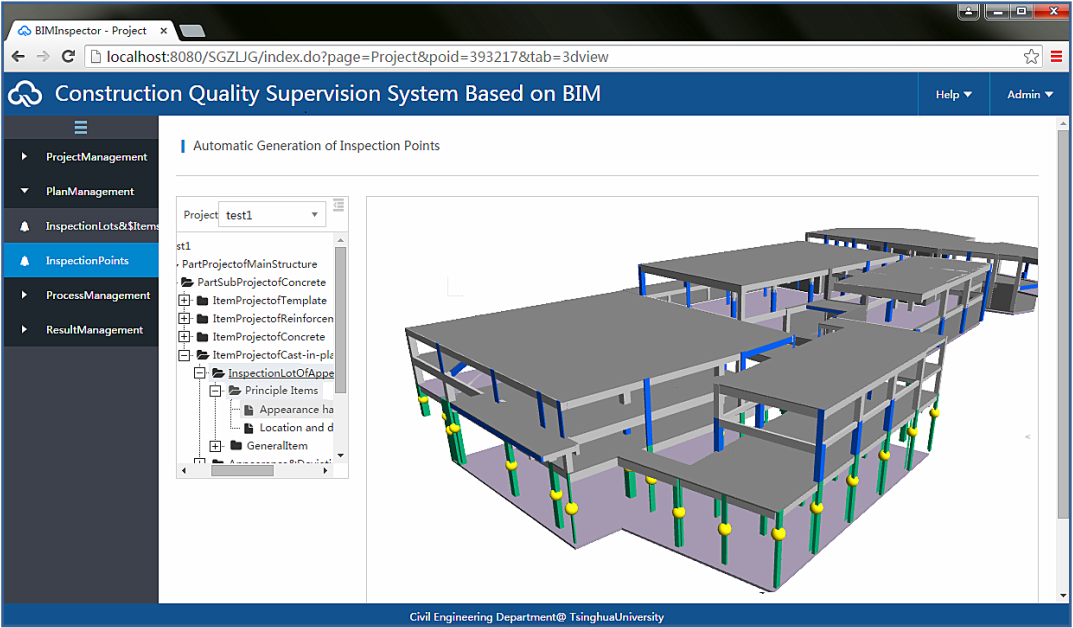


Figure 4. The generation of inspection points.

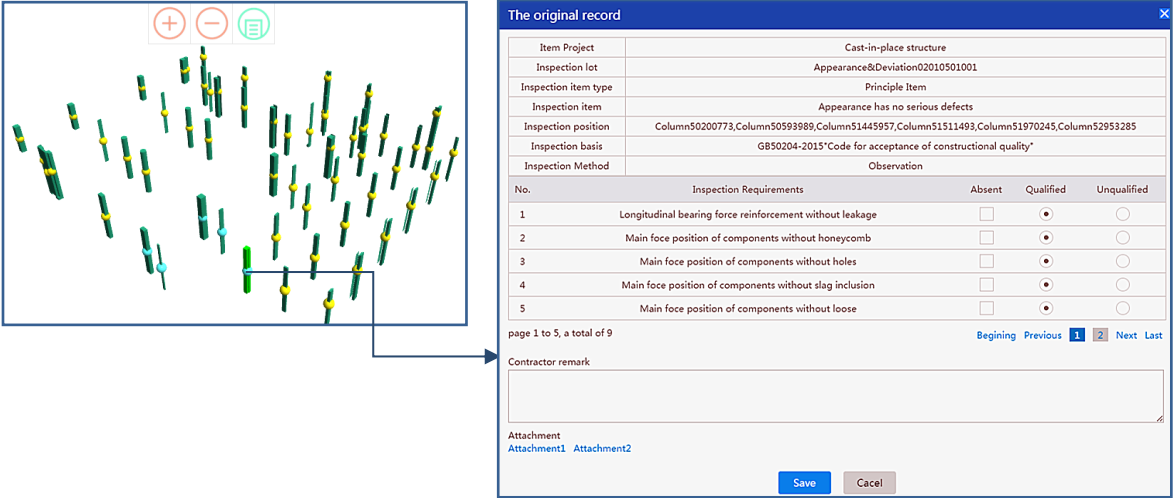


Figure 5. An example of filling out self-inspection record of "Appearance has no serious defects" item for 5 columns.

By using the commands in the category of result management, managers can view the uploaded data in time. They can check the inspection state by color of inspection points and other tags, conform the inspection progress with schedule diagram and check the relevant inspection reports. Compared with the traditional supervision process, managers can learn the situation without having to go to the site and learn more information before making decisions.

5. Conclusion and future work

In this paper, a system based on BIM was developed to improve the process of quality supervision. Firstly, the basic requirements analysis of the system was carried out. Then, an information model and an algorithm for automatically generating inspection lots, items and points based on BIM and related standards were established. Finally, the approach was implemented based on BIMserver.org and a preliminary trial use was carried out. It shows that the system makes it easier for inspectors to learn the inspection object intuitively and comprehensively before construction, more effective to filling out the customized forms without worrying about omission and

negligence especially when some standards revised, and more convenient to input the data in the original records into computers without second input so as to reduce huge workload and data falsification.

Through the preliminary trial use of the system, it is understood that a big obstacle for users is to quickly identify the corresponding inspection points in BIM models when facing the inspection against a point in a real projects. This problem affects both the convenience and the efficiency of quality supervision. Luckily, indoor positioning technology has advanced rapidly in recent years, and some research outcomes have been applied to the construction site [16, 17 and 18]. In the future, the research will focus on integrating indoor positioning technology into the approach to help inspectors locate to the current inspection points and display them on model for a better management. Besides, the mobile side of this prototype system is a little complicated to the inspectors, so it is necessary to improve the interface to make it suitable for inspectors in the later work.

Acknowledge

This research is supported by the fund of the Joint Research Center of Tsinghua University and Glodon Software Limited.

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