

A BIM-enabled Approach for Construction Inspection

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ABSTRACT

This paper presents an approach for inspection of construction enabled via building information modeling (BIM). It meets the following criteria: (1) all major inspection tasks and locations are determined before the site inspection trip; (2) inspectors can easily retrieve the prepared images generated from the BIM model and related construction information required to complete the inspection tasks without complicated manipulation of the BIM model during inspection; and (3) the inspector's tasks are straight-forward and mainly involve data collection. This means that the inspector's tasks at the construction site are well defined and free of possible interference from site engineers. In the ongoing research presented in this paper, a BIM-enabled construction inspection system is prototyped based on the proposed approach. The system framework and user interface (UI) are discussed and designed to achieve effective and efficient inspection of construction.

INTRODUCTION

Quality inspection and management play an important role during a construction project (Wang, 2007). Effective and efficient quality management is necessary for attempting to complete projects within the project budget and deadlines. With Building Information Modeling (BIM) technology, the inspection data can be integrated in a BIM-enabled platform. An engineer may review and trace issues in the BIM model and collected construction data.

Since the invention of the Personal Digital Assistant, or PDA, collecting construction site data with mobile devices reduces costs and labor time (Cox *et al.*, 2002). In addition, the mobility, durability, and compatibility of hardware and the operating system have been improved to satisfy wireless networks and mobile applications usage (Chen *et al.*, 2008). With BIM technology, mobile devices not only provide tools for making use of BIM model data but also act as a functional capability that places opportunities, demands, and expectations on IT systems (Davies *et al.*, 2013). Nowadays, mobile devices are becoming increasingly useful on a construction site. Firstly, an engineer can manipulate a 2D drawing or 3D model without the need to frequently recharge their mobile device. Secondly,

mobile operating systems and mobile applications support the use of a BIM model with numerous functionalities.

Due to the particular environment of a construction site, an barely online inspection system may not be practical. For example, during an inspection, the inspectors may enter a basement or desolate urban area. It is not possible to access the Internet or a cellular network in these situations. In addition, indoor-positioning is difficult to achieve in a construction site. The majority of navigation systems use a Global Positioning System signal that can only be used outdoors. In order to perform indoor-positioning, a wireless environment is typically required, where mobile devices can retrieve information from numerous wireless routers (Victor, 2013), but this is usually not the case in construction site.

To address the aforementioned issue, this research proposes a BIM-enabled approach that allows for offline construction inspection with mobile devices. First, with the help of the corresponding BIM model of the facility to be constructed, all major inspection tasks and locations are determined before the site inspection trip. Second, site images and related construction information required by the inspector are also prepared beforehand from the BIM model and can be easily retrieved on the construction site through offline operations on the mobile device. This also avoids complicated manipulation of the BIM model during inspection. Third, on the construction site, the inspector's tasks mainly involve data collection for the predefined inspection items.

In order to realize the above approach, a BIM-enabled construction inspection system is designed which separates the construction inspection work into two major components: an office module and a mobile module. With the office module, the inspectors decide the inspection tasks in the BIM model before the site trip. Through the use of a BIM model, the designer, *e.g.*, an architect, can even markup an inspection area or component and require it to be inspected during the construction. This can help to ensure the quality of construction expected by the designer. With the mobile module, the inspectors only need to collect data that is pre-defined in the office module. The pre-defined inspection tasks may also be assigned to site engineers. Waiting for busy inspectors to visit the site and approve the continuation of the construction may be avoided. This approach makes the inspector's tasks within the construction site well defined and free of possible interference from site engineers. In addition, the inspector's task is straight-forward and mainly involve data collection.

The objective of this paper is to discuss the proposed BIM-enabled construction inspection approach and the design of the information system that supports it. In the following sections, an application scenario is used as an example. The system framework and data structure are then discussed. Finally, this research presents the preliminary UI design for the BIM-enabled construction inspection system, including PC, tablet, and website interfaces.

APPLICATION SCENARIO

In the proposed BIM-enabled construction inspection system, the design of feedback arises from the supervisors and contractors. Both supervisors and contractors inspect the construction site, yet they are concerned about different issues. The contractors follow self-inspection issues in the construction site, and record frequently. On the other hand, supervisors regularly inspect their construction site by checking the records and the site. The supervisors and

contractors are hence in a subordinate relationship.

The application scenario used in this research focuses on the supervisor's construction inspection and contains three features: (1) the construction inspection is scheduled in an inspection proposal; (2) the issues during the construction inspection include document checking and element checking, which are numerous and varied; and (3) there are many BIM applications for construction inspection available for use on a tablet, *e.g.*, Bentley Navigator, Autodesk BIM 360 Field, Graphisoft BIMx, *etc.*

Our investigations have found that current BIM applications have some common difficulty for users. Navigation around a construction site is hindered by the zooming and rotation of a model. The elements which are inspected are usually located at the corner of the room or behind the other elements. It takes a lot of effort to keep the element in the view without being blocked by walls or other elements. In addition, site engineers may wear gloves, making it inconvenient for typing problem report.

The BIM-enabled construction inspection system is designed, summarizing these circumstances, as shown in Figure 1. The concept of a BIM-enabled construction inspection system is composed of three crucial parts: the PC interface, the tablet interface, and a web-based platform. First, a PC interface provides a tool for engineers to produce inspection issues. The plan view, 3D views are generated from the BIM model as images. The production of inspection issues and addition of views are handled in an Application Programming Interface (API) based on the modeling tools, *i.e.* Revit (Autodesk Inc., 2013) in this case. Second, the tablet interface automatically downloads the inspection data package while the inspector logs in to the tablet application. The inspector can begin taking onsite photos, recording voice messages, and typing problem keywords into the tablet application to accomplish the construction inspection. Upon completion, the inspector uploads the records to the web-based platform. Third, the web-based platform combines the PC interface and the tablet interface. It consists of two parts: the inspection data package and the inspection review platform. The inspection issues produced from the PC interface and the records produced from the tablet interface are stored in the inspection data package. The inspection review platform arranges the data from the PC interface and the tablet interface. The inspector may review and trace issues from the inspection review platform.

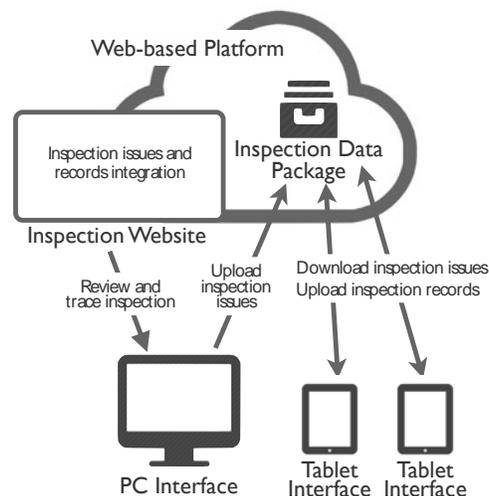


Figure 1. The concept of the BIM-enabled Construction Inspection System.

SYSTEM FRAMEWORK

The BIM-enabled construction inspection system consists of two major components: the office module and the mobile module. In order to simplify the work required at the construction site, all inspection issues and locations may be decided with the office module in advance. The issues are independent rather than an element in the BIM model. Thus, adding issues for construction inspection is not restricted. Not only can the check list for elements be added to issues, but also reminders, *e.g.*, to remember to inspect documents. The locations generated from the BIM model are displayed as images distinctly showing the details of issues, and are easily manipulated in the tablet by the inspector. Additionally, the issue order is predetermined in the office; the inspector can easily follow the instructions displayed on the tablet in order to fulfill the inspection. The issue file can then be uploaded and the preparation is complete. The inspector can easily retrieve the prepared images generated from the BIM model using the mobile module. Related construction information required to complete the inspection tasks without complicated manipulation of the BIM model during inspection can also be retrieved. Finally, the inspector can trace problems and produce documents via an inspection website.

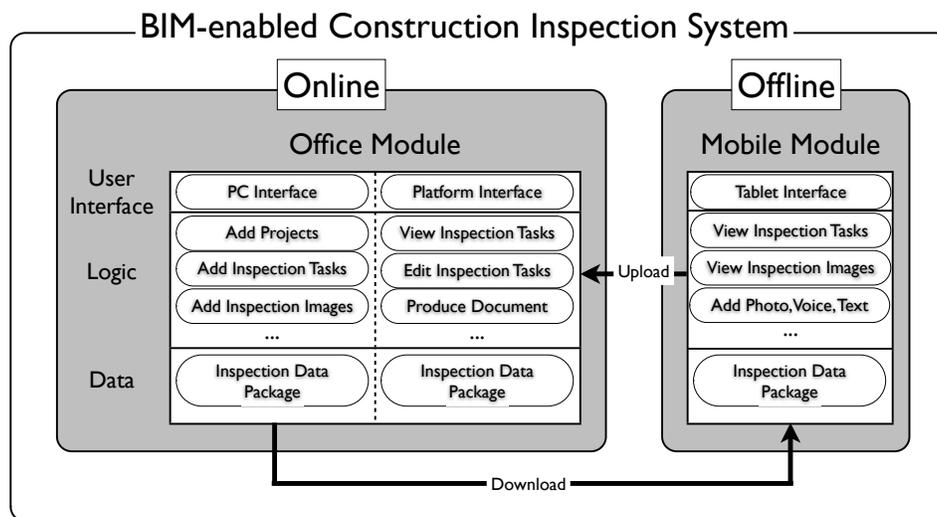


Figure 2. System framework of the BIM-enabled construction inspection system.

USER INTERFACE DESIGN

This research presents a preliminary design of the UI. There are three principles for designing the user interfaces: large buttons, minimal tablet view, and simple functionality. A construction site is a complex and busy environment. The inspectors usually have no time or patience for finding icons on the tablet. The larger the buttons it has, the more inspectors will be willing to use it. In addition, the menu navigation system provided should be as straightforward as possible to avoid confusing inspectors. The inspectors must not be distracted from their tasks in construction site and can easily access the view and functionality

when they require them; therefore, the functionality provided by the tablet must be simple to use. There is no functionality that can solve all of these conditions, but it is feasible to design a user interface that has limited functionality yet is simple to use. The UI design of Clear+, an iOS App, is largely adopted at this stage in this research.

The PC interface, shown in Figure 3, provides functionalities for engineers to produce construction inspection issues. In the left column of the window, the inspector categorizes the inspection issues. The categorization informs the inspector of the rough location of issues, *e.g.*, 1F-A1, 3F-A2, *etc.* Additionally, the right column of the window describes inspection issues. The inspector can also add precise images, including plan views, 3D views, and detailed views, generated from the BIM model to the issues. The main view of the tablet interface after the users login the system is shown in Figure 4. The main view is divided into two parts; the left side of the view shows the categorization of issues and gives the counts of unresolved issues, while the issues themselves are shown on the right side.

There are three features in the tablet interface design. First, all functions can be easily accessed with gestures. Each gesture guides the user to the corresponding function. It reduces number of buttons in the main view. Besides, gestures have a larger controlling area than buttons. Inspectors may focus on construction site and inspection issues rather than finding the button. For example, if the result of the issue is acceptable, the inspector can swipe the issue from left to right. The issue will be added an “OK” mark. On the contrary, the “X” mark is added. Second, the background color of issues changes in gradient by the order of the issues. Comparing with the issues listed in the same background color table, the gradient color background give an implicit impression of the order. Third, when the inspector taps a single issue, the corresponding plan view images, 3D images and detailed images pop up. Instead of navigating to another view, a pop up view gives inspectors more sense of position of the issue just tapped. Figure 5 shows the pop up view in the main view.

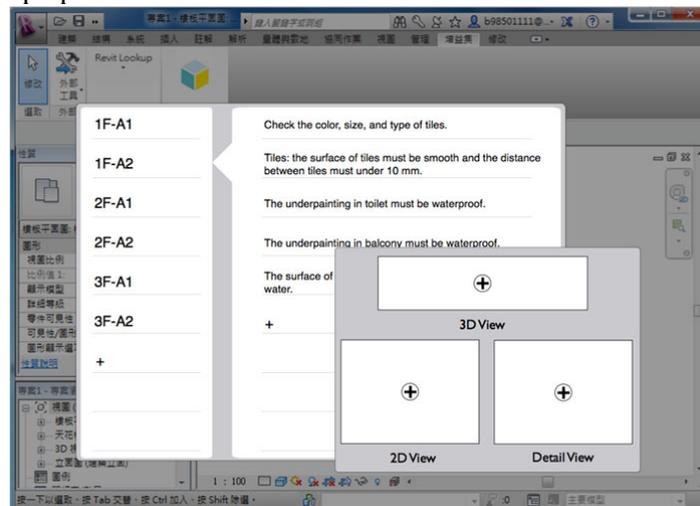


Figure 3. The PC Interface of the BIM-enabled Construction Inspection System.

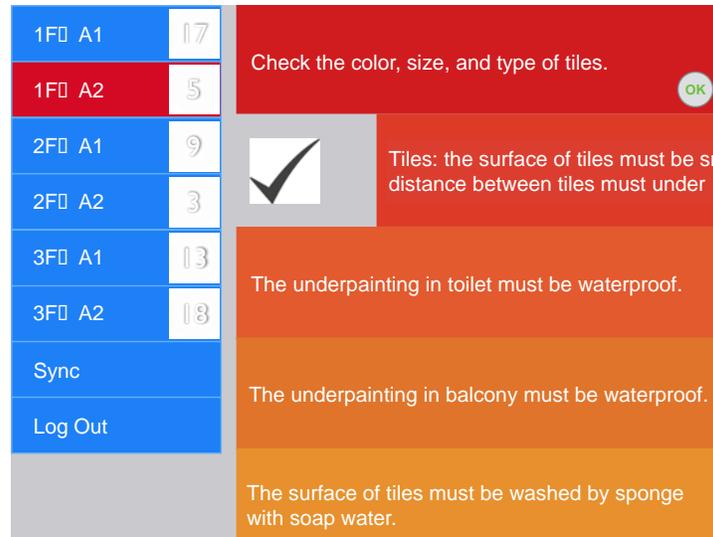


Figure 4. Main view of the tablet interface

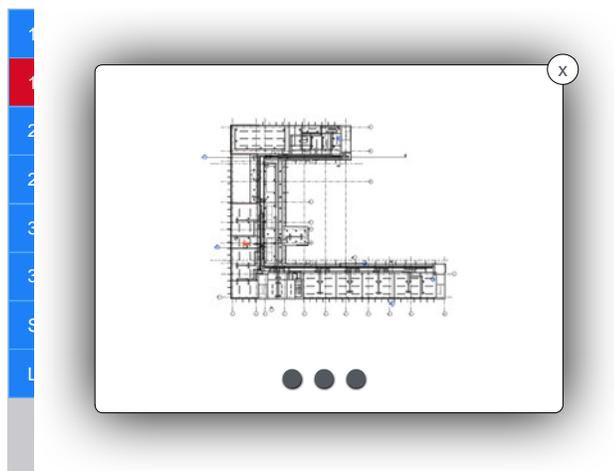


Figure 5. Pop up view of the tablet interface

The inspector uploads the inspection data package to the web-based platform after the construction inspection. The inspector then reviews and traces issues on the inspection review platform. The records generated from the office or mobile modules may be downloaded to produce a document of report if it is required. In addition to the basic functionality for reviewing and tracing issues, companies may customize their own functions in the inspection review platform to satisfy their standard operating procedures.

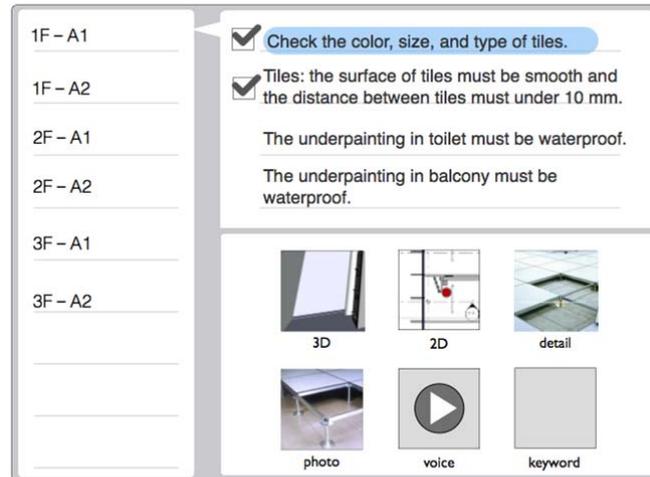


Figure 6. The inspection review platform for the BIM-enabled construction inspection system.

CONCLUSION

This research is an ongoing project to develop a BIM-enabled construction inspection system. The system supports predefined construction inspection tasks and allows offline inspection operation with mobile devices in the construction site. The many advantages of this proposed approach have been discussed in the paper. It is believed that this approach is not only easy to use and cost-effective but also can further improve the quality assurance of construction work.

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