ENHANCE ARCHITECTURAL HERITAGE CONSERVATION USING BIM TECHNOLOGY

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Abstract: Common problems tend to surface during the restoration and maintenance of wooden structures for architectural heritage: (1) recording and communicating geometric and non-geometric information, (2) integrating and managing the multiple phases of construction and (3) the structural damage that can be incurred during the dismantling process. This leads to less confidence in the quality of restoration and maintenance. This study considers the traditional wooden structures in Taiwan as a basis to discuss the issues faced during restoration and the gap in communication between designers and builders. Using new techniques, resources and the concept of BIM, a plugin is developed for guiding restoration. It serves as a BIM-based communication platform for designers and builders, enabling the real-time exchange of information to minimise any gaps that may exist between the designers’ information and that of the builders. This allows information related to the restoration to be more accurate and offers the assurance that the traditional architecture retains its original structure and value.

Keywords: Architectural heritage; conservation; digital achievement; BIM; wooden frameworks.

1. Introduction

The study of the Building Information Model (BIM) has been steadily developing over the past ten years with BIM technology being widely used in different ways. Most research has focused on using BIM technology for planning and designing new buildings but recently research has been extend-
ed to using this technology for the restoration of existing buildings and the conservation of Taiwan’s architectural heritage. Because of the importance of conserving our architectural heritage, using digital technology as a means of archiving and storing information about the buildings has become an alternative approach to addressing the best way to preserve them. However, the application of BIM for the conservation of historical buildings is still facing various challenges (Volk et al, 2014).

In this research, Taiwan's traditional wooden structure is taken as an object for restoration. There are common problems encountered during the restoration process and maintenance of wooden structures:

- The recording and communicating required geometric and non-geometric information.
- Managing the integration of the multiple phases required in the construction.
- The process of dismantling the building, which could lead to structural damage.

These factors can lead to uncertainty regarding the quality of any restoration and maintenance work. It is important that information related to any restoration is accurate and assurances provided that these traditional buildings retain their original structure and value.

In this article, guidance regarding how restoration should be done is given. The use of new techniques, resources and the concept of BIM is developed as a communication platform between designers and builders. It enables the real-time exchange of information to minimise any gaps that could have existed between the designers and those doing the construction.

2. Research problems and tasks

During the lifecycle of any traditional building, every aspect from designing, constructing, restoring and, ultimately, demolishing the building is normally carried out under the supervision of an expert. Therefore, the experts know a great deal about restoration. While some important restoration drawings are in 2D format, unfortunately 2D drawings cannot present all the spatial information, such as hidden parts of the building. During the restoration construction phase, inadequate or incomplete information can result in communication problems occurring during the design and construction phases, thus making it difficult to ensure the quality of the restoration.

Insufficient information and the integration of information present different problems in restoration work. In this case, three stages are established for the restoration procedure:
• **Stage 1. Information modelling and decisions about the restoration:** (a) Integration of information about the geometric and the non-geometric model. (b) Traditional components can’t be standardised. (c) Restoration analysis, efficiency and suitability of the decision.

• **Stage 2. Site construction records and management:** (a) Lack of understanding of the restoration drawings in the design phrase and the construction phrase. (b) Improper management of the restoration data available for the construction of wooden buildings. (c) The representation of the hidden components does not correspond to the drawings of the repair designs after the components have been dismantled.

• **Stage 3. Restoration schedule and reporting:** (a) Poor communication increases difficulties in management. (b) Reporting takes up the time of those employed to do the work. (c) Unexpected occurrences cause losses in revenue and time.

According to the three stages above, restoration projects would progress more efficiently if all data were integrated and collated on a daily basis. Therefore, to improve the factors noted in these three stages, BIM technology is applied as a guidance system during the restoration of historical buildings. However, most BIM technologies introduced into the process of preserving the cultural heritage emphasise the use of a 3D reconstruction of the geometry. They also design a surface model using 3D point cloud processing with 3D scanning technology, parametric modeling methods or virtual reality technology. This is so that there can be a direct simulation by means of the automatic processing of data to be able to visualise the more complex models (Shah and Mäntylä, 1995; Arayici, 2008; Chévrier and Perrin, 2009; Boeykens and Neuckermans, 2009; Fai et al, 2011; Baik et al, 2013; Murphy et al, 2013). However, there is a lack of research into the communication between the designers and builders and a discussion of how the design drawings are interpreted and presented by the professionals in different fields.

The goal of the BIM-aided restoration guidance system, as described in this article, is to integrate information from the various professionals into a model. It also aims to ensure coordination and collaboration, update and improve the model and give feedback to every participant. This will open up opportunities to gain knowledge and to share information so that we can communicate effectively. This will lead to proficiency in the project and will keep down the cost of the design, composition, construction and the management of the maintenance work.
The task of this research is shown below:

- **Set up BIM components of a wooden framework and the classification of the information structure**: All the data relevant to the restoration, especially the history of each stage of the wooden framework, are included in the BIM model for analysis and categorisation.

- **Set up an information model of the deconstruction and construction of the wooden framework**: Introduce an evaluation method of the process of deconstruction and a structural analysis; optimise the analysis of the deconstruction and restoration procedure.

- **Restoration-aided design and guidance application**: Help in the communication between designer-craftsman and craftsman-craftsman. Verifying the feasibility of information about the actual construction.

3. **BIM component development and classification**

3.1. **WOODEN FRAMEWORK STRUCTURES**

The object of our research is the Hu Chi Temple located in Ma Tou, Taiwan. This temple belongs to the Diedou category of structure and every component is named according to its position; for example, the purlin and ridge that are situated in front of the main hall. However, coding by means of the spatial order in the paperwork shows that these lie along the x-axis and the y-axis, forming X1-X6-Y17 and X1-X6-Y18. In addition, for the application of the restoration-aided design and for construction management, another code will be added, based on the order in which the wooden component will be deconstructed.
The composition of the traditional wooden framework is complicated; every component has particular name. It is difficult to establish a label using a word for the coding of a component according to its spatial position. The label needs to contain essential information like the material classification, the size, the restoration record, time taken to restore, who the craftsman was, among other information. Therefore, the labeling identification code of components has to be clear and be able to be easily checked according to the visualisation model. In short, when using the BIM system for restoration, we first need a coding system, and only after this do we need to create a visualisation geometric model and non-geometric model for information.

3.2. WOODEN FRAMEWORKS

3.2.1. Information and visualisation

Wooden structure mapping includes 3D point cloud, primitive data and pictures. Each component can apply BIM to create a plan, show elevation and section and at the same time, visualise the relationship between the measurements and spaces linked with picture. Besides presenting the component in 3D, BIM can show the damaged part of the component in a timed overlay.

![Figure 2. 3D modeling showing the information part of the overlay in Revit](image)

3.2.2. Detail field

A list of items for the restoration of historical buildings for non-geometric information is created mainly to describe the characteristics of a component and information about components that can’t be visualised. These are normally noted by means of words and digits. The list is divided into six sections:

- Coding: Entire frame ID, unit ID, status ID, traditional ID, coordination
- Dimension of component: radius, width, and thickness.
• Materials and components: material, source, cost.
• Restoration craftsman: craftsman, contact.
• Restoration period: date of previous restoration, date of entire restoration.
• Restoration strategy: construction of restoration, level, restoration method.

Integration of the information to do with set up and time will allow staff to grasp all the information about the restoration of the wooden structure. In future, this research will be integrated with API and APP, leading to improved efficiency as any exchange of information or revisions will be instantly updated in the design stage and the construction stage.

3.2.3. Dismantling information
Every wooden component has an identification code: the damaged area, the mortise, the name along with the source of the material and the order of assembling/dissembling are all specified. To present these traditional wooden structures clearly, a few aspects are crucial. These include the arrangement of the space, the function of the structure, and the special characteristics of the different wooden components. More specific information about these areas helps to establish a 3D view, making it easier to address the exact issues. Furthermore, it is advised to work with technicians and architects to establish a 3D mock-up model. Simulation of the assembling and dissembling work process can be performed on this; it also serves as a preview structure and can be used to identify potential errors and prevent their occurrence.

4. The BIM-aided restoration guidance applications
4.1. CONSERVE COMPASS SYSTEM IMPLEMENTATION
In the introduction, we referred to some of the common problems that can be encountered during the process of restoring and maintaining wooden structures. This article attempts to find suitable solutions to these problems during the restoration work through the development of the BIM-aided restoration guidance system. We called it the Conserve Compass (C-Compass) system and it includes Revit plugin and mobile Apps. The main purpose of the C-Compass system we developed here is to assist with communication and coordination between the design of the repairs and the construction work on site. The data are shared immediately and on a regular basis. Further, the data shared is extensive in order to minimise any construction error. Therefore, the historical buildings are accurately preserved.
The main tasks of the C-Compass Plug-in are:

- The geometric and non-geometric data from designers or architects can be sent to the C-Compass cloud server through the Revit Plug-in.
- The construction managers capture the graphic and non-graphic data through the C-Compass cloud server. The parts to be repaired, the damaged cases, repair materials and other information should be reconfirmed before the construction begins.
- Instant feedback can be sent to designers from the construction site if the repair data is not understood or needs to be changed.
- Project and construction records, and reports digitally achieved are completed.

4.2. USING THE INTERFACE DESIGN

Based on the three stages of repair work mentioned in Chapter 2, five panels are established on the C-Compass plug-in ribbon toolbar: Model, Strategy, Communication, Record and Schedule. The Model and Strategy panels are derived from the model information and the restoration decision stage. The Communication and Record panels are derived from the site construction records and the management stage. The Schedule panel is derived from the restoration schedule and report stage. The function of each panel is described as follows:

There are two main panels and functionalities in the design stage for model information and restoration decisions:

- The Model panel helps designers to import the model into the Revit software seamlessly, convert the revised file and add public parameters.
- The Strategy Panel helps designers to get the data on the history of repair design strategies and provide suggestions.
Figure 4. The description of system workflow and panel function

There are two main panels and functionalities both on the Revit toolbar and Mobile Apps in the construction stage for the site construction records and management.

- The communication panel on Revit transmits the designers’ repair assignment to the field.
- The communication button on Mobile Apps assists the construction site managers to review and execute the assignments from the designers and get feedback to the designers immediately. Texts, pictures and videos that need to be included can be sent back by a mobile device to the cloud.
- The record panel on Revit helps designers to update replies about the assignment reply by the builders and complete the blank parametric field of the model.
- The record panel button on Mobile Apps help construction site managers to develop a Gantt chart for checking the progress and do the daily report.

After the project has been completed, a database can be built. This includes data such as an arithmetic information chart, a restoration design chart, identifying new damage that came to light during the dismantling process, unexpected damage, construction progress, material costs, etc. Designers and construction site managers can use the schedule panel to generate a construction diary, reports and charts.

5. Conclusions and future prospects

This research has discussed the restoration of Taiwan’s ubiquitous communication problems between designers and builders in the building industry. To do this, it has introduced new technology and the concept of BIM to inte-
grate all the data related to restoration. During restoration, applications are introduced to improve the quality of construction. The development of a plug-in application showed the following results:

- During the design phase, using BIM with both 3D visualisation and captions, designers will not have to be on the construction site. Working through the cloud, they can instantly access the correction of restoration data.
- During the construction phase, the application of BIM can dismantle a complex component and recompose it through a visual information model. At the same time, BIM can present it as a 3D model immediately, receiving feedback and a new design instantly.
- In the final stage, the construction report is presented in dynamic form (geometric and non-geometric information), different restoration information is provided and collections used for users through BIM.

In the future development, we aim to try to convert design data into information, introduce the application of 4D/5D project management to pass on this knowledge to the next generation. In addition, the application of the Geographic Information System (GIS) and Augmented Reality (AR) will be added. Currently, BIM, PMSI and GIS seldom intersect with each other and are not in parallel use. Therefore these systems can be combined and integrated for management needs in whole life-cycles.

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