IMPROVING TRADITIONAL BUILDING REPAIR CONSTRUCTION QUALITY USING HISTORIC BUILDING INFORMATION MODELING CONCEPT

T. C. Wu[a *], Y.C. Lin[b], M. F. Hsu[c], N. W. Zheng[a], W. L. Chen[a]

[a] Department of Civil and Engineering Management, National Quemoy University,1, University Rd., Jinning Township, Kinmen, Taiwan； +886-82-313518；

E-mail：tsung_chiang@nqu.edu.tw

[b] Assistant researcher, College of Planning and Design, National Cheng Kung University,1, University Rd., Tainan, Taiwan； +886-6-2757575；

E-mail：hsiao_na@hotmail.com

[c] Professor, Department of Architecture, National Cheng Kung University, Tainan, Taiwan;

E-mail：minfu@ncku.edu.com

KEY WORDS: historic building information modeling, construction records, 3D laser scanning technology, 3DGIS

ABSTRACT:

In addition to the repair construction project following the repair principles contemplated by heritage experts, the construction process should be recorded and measured at any time for monitoring to ensure the quality of repair. The conventional construction record methods mostly depend on the localized shooting of 2D digital images coupled with text and table for illustration to achieve the purpose of monitoring. Such methods cannot fully and comprehensively record the 3D spatial relationships in the real world. Therefore, the construction records of traditional buildings are very important but cannot function due to technical limitations. This study applied the 3D laser scanning technology to establish a 3D point cloud model for the repair construction of historical buildings. It also broke down the detailed components of the 3D point cloud model by using the concept of the historic building information modeling, and established the 3D models of various components and their attribute data in the 3DGIS platform database. In the construction process, according to the time of completion of each stage as developed on the construction project, this study conducted the 3D laser scanning and database establishment for each stage, also applied 3DGIS spatial information and attribute information comparison and analysis to propose the analysis of differences in completion of various stages for improving the traditional building repair construction quality. This method helps to improve the quality of repair construction work of tangible cultural assets of the world. The established 3DGIS platform can be used as a power tool for subsequent management and maintenance.

1. INTRODUCTION

In Taiwan, the process of historic building restoration is recorded in the construction records, covering working procedures, materials, and methods. Those recorded also ensure the construction quality meeting the design requirements. In practice, the construction records have only slight influence on guaranteeing the construction quality because the 3D (three-dimensional) spatial information of the building before, during, and after restoration is replaced to make comparative analysis impossible. The feasible solution to this problem is proposed after the popularization of 3D laser scanning technology and the application of BIM (Building Information Modeling) concept. The 3D laser scanning technology can obtain the 3D coordinates and color information of high density and super-high accuracy of the building façade. It provides an important tool to preserve the conditions of the building at different stages of the construction process. The concept of BIM is applied to decompose the 3D digital components of the historical building, and attributes data are assigned to various components, thus obtaining the cross-analysis results of spatial information and attribute data. The proposed model can enhance the capabilities of the construction records of traditional buildings to monitor the construction quality. Meanwhile, the comprehensive 3D digitalized records have potentials and values for data storage and future management applications.

BIM is the integrated 3D database on the basis of 2D architectural drawings of the building. Through the conflict analysis on the 3D data established according to the drawings, the reasonable architectural design can be developed for the planning and control during the construction process. However, as to historic buildings, the main difference in the establishment of the 3D database by applying the BIM concept is that the building should be digitalized first to obtain BIM in a “reverse” way. The 3D building database established in this way is known as HBIM (Historical Building Information Modeling). Since the purpose of this study is to improve the traditional construction record model of historic buildings, 3D laser scanning technology is applied in the relevant 3D building model to develop the 3D point cloud model. The attribute descriptions of relevant component models are obtained by the investigation and research procedures of traditional buildings (Murphy et al, 2011). Among the various methods to acquire the BIM and HBIM 3D digital models, this study uses 3D GIS platform (ArcScene) as the database system for the historic building 3D model as well as its corresponding drawings, attribute

descriptions, images, videos and text data (Berlo et al, 2010), and performs the 3D layer-based management of historic buildings by using the concept of "sub-layer". The purpose is to monitor the milestones in the course of historic building construction process. With the National Historic Sites of the Guan-ao Longfeng Temple and Qiu Lian-gung's Mother Chastity Arch in Kinmen as the targets, this study attempts to establish Taiwan's historic BIM model as the operational reference of the construction records of restoration projects in the future.

2. RESEARCH METHOD

This study referred to C. Dore, M. Murphy (2012) who mentioned the implementation of the restoration project of the historic street of Henrietta by Dublin Institute of Technology, Ireland, using 3D GIS and HBIM technology. By integrating 3D laser scanning technology, Sketchup and 3D GIS technology, the method preliminarily establishes HBIM platform. According to Fai (2011), this study integrated 3D laser scanning technology, AutoCAD, Civil 3D, SketchUp and Revit technology for the preservation of historic buildings and surrounding landscape. The past, present and future landscape is simulated as the basis for the preservation and repair of cultural assets. This concept offers an important reference for the record and analysis of 3D results of the phased restoration construction.

Based on the above research purposes, this study used BIM as the concept, and integrated 3D laser scanning technology, 3D point cloud modeling technology, historical documents, historical buildings on-site survey data, and 3D GIS platform to study the establishment of HBIM management system. The difference between this study and previous works is that no commercial BIM software platform has been used for 3D modeling. Instead, classified and segmented 3D point cloud models and components are input into the software of SketchUp for 3D modeling, and the corresponding attribute data are acquired using the XML grammar and Excel sheets. Besides avoiding the loss of 3D building model in data format conversion process, the research procedure is as shown in Figure 1.

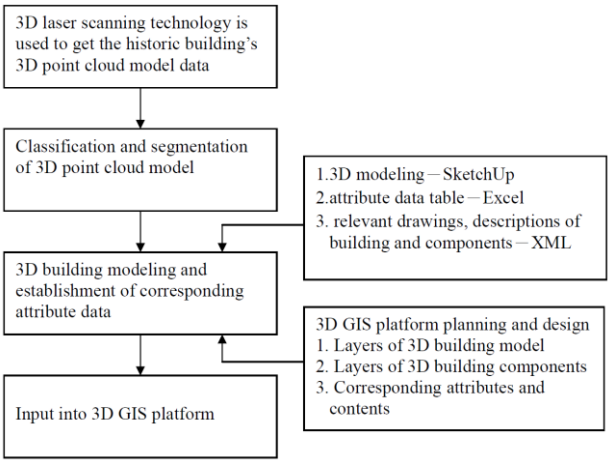

Figure 1. Research procedure

2.1 Research Subjects

Considering the convenience of location selection, this study chose a residential house in Jinning Town, Kinmen County as the target (Figure 2). Simulation was conducted to establish of 3D data for the conditions of the residential house before the restoration project using the proposed HBIM operational model. The residential house is a traditional Minnan style building commonly seen in Kinmen County, and is a representative of the local architecture style.

Figure 2. Residential house in Jinning Town, Kinmen County

2.2 Establishment of 3D Spatial Information

HBIM is different from the BIM 3D digital models. According to the relevant design diagram models, this study applied 3D laser scanning technology to obtain the 3D point cloud model data of the research target. To meet the requirements of the scanning of buildings as the subjects and take into consideration of the effective scanning distance of 3D laser scanner, as well as the relationship between the point accuracy of point cloud data and point density, this study used FARO Photon 120 3D laser scanner as the scanning tool (Figure 3).

The effective scanning distance of the equipment is 0.6~120 m; the error is 2cm when the scanning accuracy is 25 meters, the scanning speed is up to 796,000 coordinates per second. The above configuration can obtain the 3D point cloud data of high density and high accuracy, and is appropriate for the scanning and digitalization of buildings.

Figure 3. FARO Photon 120 3D laser scanner

2.3 Modeling of 3D Building Components and Establishment of Corresponding Attribute Data

The relevant 3D point cloud models of the building before restoration is reviewed in terms of point cloud model overlay accuracy to ensure the model accuracy. Regarding the 3D point cloud models that meet the accuracy requirements, according to the classification and segmentation of building history scholars, this study established the 3D digital models of the building and relevant detailed components. Google SketchUp and its modeling plug-in Pointools Plug were used because the tools can simplify the 3D modeling process of the 3D point cloud data, and considerably reduce file conversion time. Meanwhile, it can keep high quality visual image and accuracy, and rapidly increase the 3D modeling speed. In addition, the relevant attribute data are recorded in XML format.

2.4 3D GIS Platform Planning and Design

This study did not use the commercial BIM commercial software (AutoCAD Revit, Bentley Architecture, ArchCAD, Graphisoft), but adopted the BIM construction concept. The 3D building model data were directly input into the 3D GIS platform to establish the convenient and low-cost HBIM construction model. However, the 3D GIS system as the platform of information relating to 3D building model should be planned and designed according to the specific background and maintenance management model. To comply with the characteristics of "layered" storage and management of the spatial information and attribute information of the 3D GIS platform, the major components and detailed components of the classified 3D building model after modeling as well as the corresponding attribute data are input into the 3D GIS database in a "layered" architecture. This can achieve the purposes of saving storage space, fast accessing to data, overlay spatial analysis and 3D visual demonstration.

3. RESEARCH RESULTS

This study applied 3D laser scanner in the digitalized operation of the research target. Through "conjugate ball overall mode", the multi-station 3D point cloud data are combined into the 3D point cloud model, and the relevant overlay accuracy meets the requirements of the building scanning specifications.

Through the point cloud classification and segmentation process of the 3D point cloud model, this study applied the 3D modeling technology of the software of SketchUp in the construction of the component 3D digital models of the research subjects. The 3D spatial information model and relevant attribute data of relevant components were input into the 3D GIS platform process by the layered storage and editing method. The BIM concept was applied to construct the 3D digital building component models of the research target into a database platform of HBIM. This study followed the traditional building component classification principles upon the layered storage and demonstration function provided by 3D GIS (Fig. 4). In the future, it can be applied in the construction and updating of achievements of various stages or the spatial overlay differential analysis of different image layers and achievements of different stages.

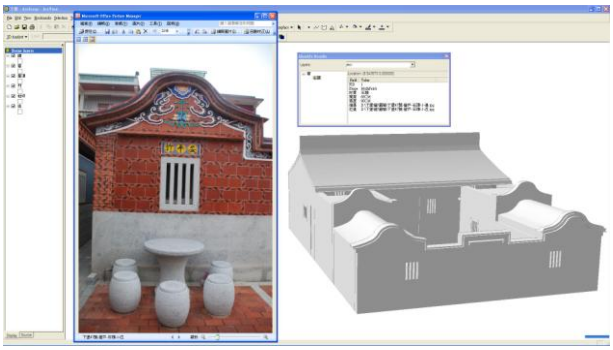

Figure 4. 3D GIS-based HBIM database platform

4. CONCLUSION AND SUGGESTIONS

This study proposed that the integration of BIM concept, 3D GIS platform and 3D laser scanning technology can construct the 3D spatial information and attribute data of the historical buildings to be restored and repaired. It can be a multi-functional platform of storage, editing, analysis and demonstration. For historic buildings, the proposed method can provide 3D conditions before, during and after restoration, and help the digitalization of construction records as well as monitor the construction quality. After the construction, the construction process recorded in the platform can be used for the follow-up management and maintenance of the historic building.

REFERENCES

Murphy M, McGovern E & Pavia, S 2011, 'Historic Building Information Modeling - Adding Intelligence to Laser and Image

Based Surveys', paper presented to 4th ISPRS International Workshop, 3DARCH 2011: "3D Virtual Reconstruction and Visualization of Complex Architectures" Trento, Italy, 2-4 March 2011.

Berlo, Lv & Laat, Rd 2010, 'Integration of BIM and GIS: The Development of the CityGML GeobBIM Extension', paper presented to 5th International 3D GeoInfo Conference, November 3-4, 2010,, Berlin, Germany, Berlin, Germany.

Dore, C., Murphy, M., 2012, 'Integration of Historic Building Information Modeling and 3D GIS for Recording and Managing Cultural Heritage Sites', 18th International Conference on Virtual Systems and Multimedia: "Virtual Systems in the Information Society", 2-5 September, 2012, Milan, Italy, pp. 369-376.

Fai, S, Graham, K, Duckworth, T, Wood, N & Attar, R 2011, 'Building Information Modeling and Heritage Documentation', paper presented to XXIII CIPA International Symposium, Prague, Czech Republic, 12th-16th September.