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Research on Protection and Restoration of Heritage Buildings Based on Heritage Building Information Model (HBIM) Technology and Its Application

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ABSTRACT

In this paper, a heritage building information model (HBIM) is constructed through multi-dimensional data of cultural heritage buildings such as literature data, picture data, and 3D scanning, and through point cloud data processing and Revit software. The parametric component library of cultural relic buildings extracted from the model can be used for the restoration research of cultural relic buildings. The feasibility of HBIM technology was proved by a case of protection and restoration of heritage building. Through the multi-dimensional data collaborative platform under HBIM technology, it provides a reference for the digital retention, systematic expression and scientific management of cultural relic buildings, and develops new technologies and material means for the protection, repair, inheritance and creation of cultural relic buildings, which can realize the multi-party collaborative management of the informationization of the full life circle of cultural relics.

Keywords: *heritage building information model (HBIM), point cloud data, protection, restoration, full life circle*

I. INTRODUCTION

The constant emphasis on the protection of cultural relics by countries around the world has led to a sharp increase in the number of cultural relics protection units announced by various countries. By the end of 2019, China had announced a total of 8,058 national key cultural relics protection units in total, including 3,112 historical and cultural buildings, accounting for 61.5% of the total. [1] With the increase in the number of cultural relic buildings, the requirements for basic data collection, technical protection and restoration of cultural relic buildings have also increased accordingly. Building Information Modeling, or BIM for short, is a digital model that integrates all the physical and functional characteristics of a building during its full life circle [2]. Heritage Building Information Modelling (HBIM), an interactive parameter object based on survey data of documents and images, constitutes an information model representing cultural heritage building elements. It is a new technical means for the protection and management of heritage buildings. [3] With the continuous development of information technology, building information models can be combined with 3D scanning, 3D printing, GIS, VR and other technologies, [4-10] to realize a data resource platform that meets the information display, management and monitoring of cultural relic buildings. [11] Through the multi-dimensional data collaboration platform, new technology and material means have been created for the protection, repair, inheritance and development of heritage buildings. [12] The units of protection, management, planning, design and construction of cultural relic buildings can acquire the dynamic data of cultural relic buildings in time through this platform, which can be used as the basis for daily management, protection and restoration.

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II. CONSTRUCTION OF MULTIDIMENSIONAL HERITAGE BUILDING MODEL BASED ON HBIM TECHNOLOGY

The multi-dimensional cultural relic building model based on HBIM technology is based on literature research, combined with point cloud data obtained from 3D scanning, and supplemented with local surveying and mapping data. Using BIM technology related software, it is to build a shared data platform of cultural relics and building information models including existing building entities and historical data ("Fig. 1").

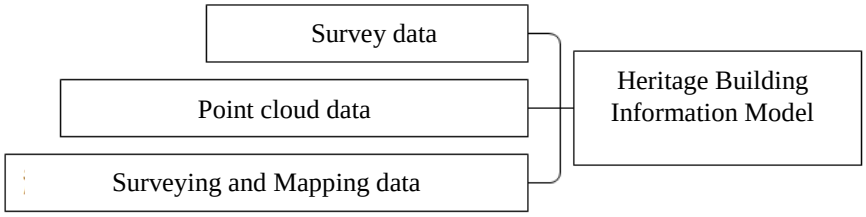

Fig. 1. Construction of a heritage building information model (HBIM).

A. *Survey data*

The survey data of cultural relic buildings mainly refer to the data obtained through the research of relevant historical documents, including data of text information and picture information ("Fig. 2").

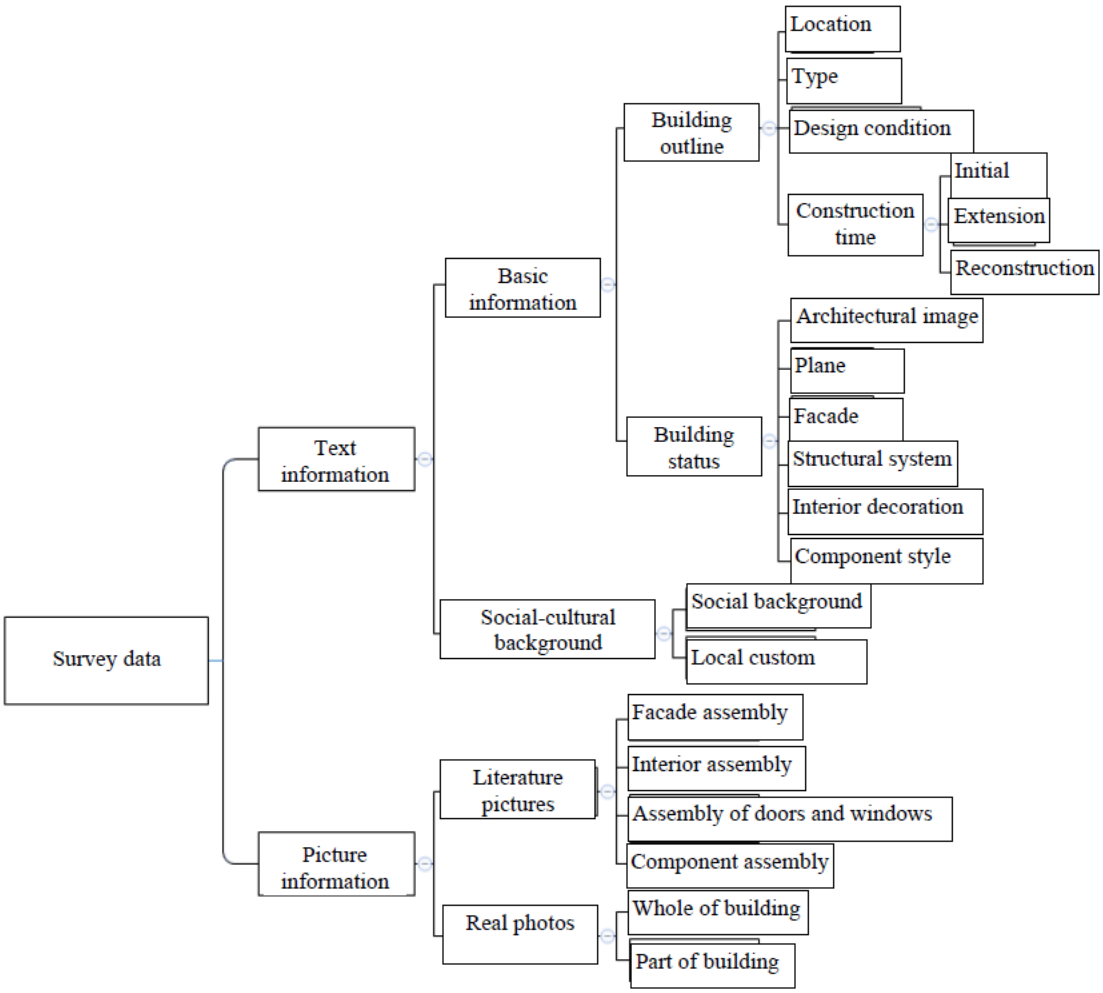

Fig. 2. Survey data content.

1) Text information: Each heritage building is a unique calendar carrier. By studying the style, structure, materials, technology, and evolution process of heritage buildings, it can in turn verify or make up for the content of the history of architecture, art, and social development. Historical literature data mainly includes the basic information and cultural background of heritage buildings ("Fig. 2").

The basic information includes the survey of the building and architectural condition investigation; the

survey of the building includes the text description of the building type, such as the location, type, and design status of the heritage buildings, and the construction time (such as initial construction, expansion, and reconstruction); architectural condition investigation refers to the historical records of architectural styles, planes, facades, structural systems, interior decoration and component styles. ("Fig. 2").

Heritage buildings are not only technical and artistic, but also have rich social characteristics as a product closely related to people; therefore, to investigate the history of architecture, it is necessary to investigate its social and cultural background, to understand the social background of heritage building construction, regional customs and other written records ("Fig. 2").

2) Picture information: The picture information refers to the collection of picture records of the historical stages of the building, including pictures in the literature and real-life photos of cultural relic buildings found in each year; picture records of cultural relic building status is one of the forms of survey data and cannot be replaced by text. The picture can provide a scientific comparison basis, it can most clearly and intuitively reflect any changes in the building; pictures can be used as basic information for reference at design time, such as facade compilation, interior compilation, door and window compilation, component compilation, etc.; by comparing the pictures before and after, it can discover the changes in the damage status of the building, to understand the original state of the heritage buildings, and avoid damage to the building during the repair process. The picture can capture the moment of the object, can restore a lot of details, high information density, and good integrity. Therefore, it can enrich the survey data ("Fig. 2").

B. *Construction route of HBIM based on point cloud data*

The point cloud data is mainly obtained by 3D laser scanning. Multi-site scanning can be performed on the inside and outside of cultural relic buildings. The scanned data must undergo data noise reduction processing to obtain a complete point cloud data model for heritage buildings [13-17] ("Fig. 3");

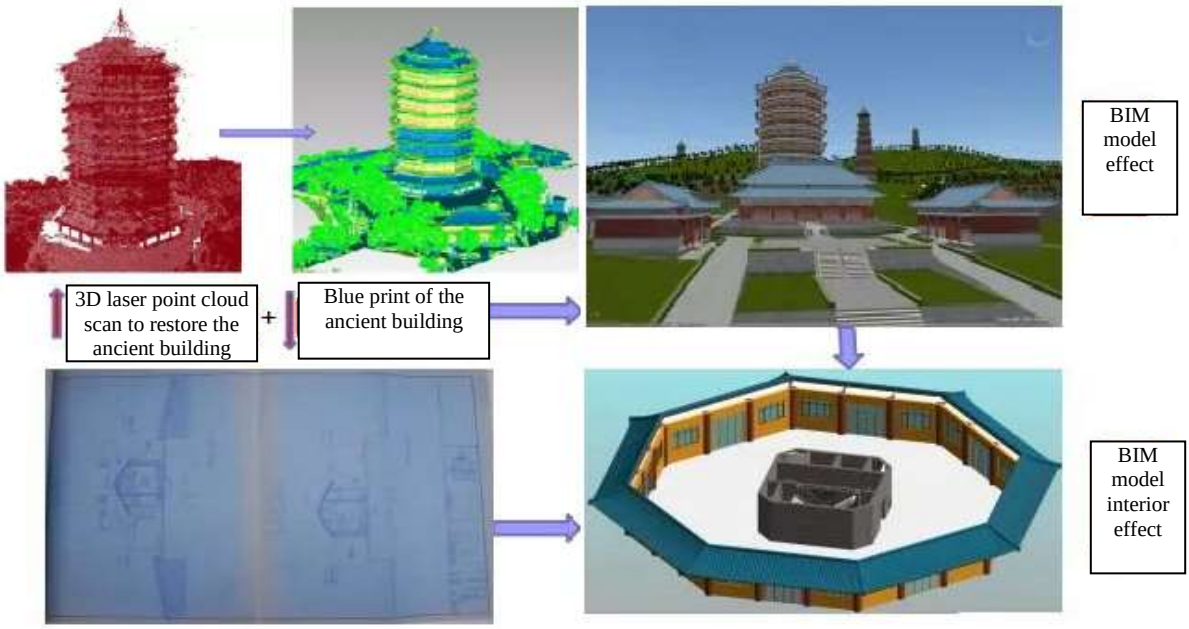

Fig. 3. Overall model of heritage building based on point cloud data.

Through related data processing software, it can build a 3D model of a heritage building based on point cloud data. The specific steps are as follows:

- Point cloud data is imported into Revit software to create 3D models;
- Then it is to extract components from the model, build component libraries such as platform foundations, columns, beams, square-columns, joists, purlins, walls, doors, windows, and roofs, and combine survey data to add material and attribute information to the component library [18];

- Next, it is to survey and map the decorative lines and patterns of heritage buildings on the spot, and combine historical data, literature and social and cultural background and other survey data to build a decorative pattern library of heritage buildings.
- The surveying and mapping data is supplemented to realize the optimized model and achieve a good matching level between the model and the real object.

The 3D laser scanner can quickly obtain complete, high-precision point cloud data; no direct contact with the observation target is required, which avoids secondary damage to historical relics; the 3D model established can be saved as a copy of the real cultural relics, which is of great significance for the protection, restoration and research of cultural relics; digital restoration of damaged artifacts is possible, and digital models can also be used for virtual presentations and Internet roaming. By extracting point cloud data from different periods for analysis, it can find the slight changes in distortion, deformation, and overall flatness of the ground, such as beams, purlins, square-columns, and walls of ancient buildings. Through the analysis of the elevation deviation of the rainbow chart, the specific value of the damage and disease is obtained [18]. In view of the above problems, timely repairs can be made to avoid the destruction of cultural relics. Through the overall 3D scanning and texture collection of the building, a high-precision 3D model is generated, and the restoration plan is considered by using the virtual repair model as an experimental object. The damaged and diseased parts are pre-repaired, and the plan for the ancient building repair is scientifically formulated. Using virtual roaming software, the dynamic digital display of static digital models enables professionals to intuitively query the building's internal structure, component details, texture and color, etc., and display the traditional cultural heritage building culture in all directions.

Based on the point cloud data, the heritage building information model realizes the "parametric" statistics and naming of ancient building components, and provides a reference for the digital retention, systematic expression and scientific management of heritage buildings, which can realize the information management of the full life circle of heritage buildings.

III. EXAMPLES OF PROTECTION AND RESTORATION OF HERITAGE BUILDINGS BASED ON HBIM TECHNOLOGY

The Heritage Building Information Model (HBIM) provides strong technical support for the method of repair design, which makes the analysis and design of complex values and their carriers simple and easy. The Ruiguang Tower Restoration Project in Anhai Town, Jinjiang City, Fujian Province, China is a case of heritage building protection and restoration based on HBIM technology.

A. Survey data

According to literature records: the original east and west temples in the south of Anhai Township had their own towers, and the east tower has collapsed 298 years ago; the west tower, named "Ruiguang Tower", was renamed "Wenming Tower ", commonly known as "White Pagoda", and there was a saying in the ancient that "白塔点灯，金榜题名 (When people have seen the White Pagoda lights up, he would succeed in the government examination)", which is widely spread. The tower is located at the bridgehead of Anping Bridge (Wulixi Bridge), one of the first national key cultural relics protection units. It was built in the Southern Song Dynasty with the remaining funds for the Anping Bridge. In the 34th year of the Wanli period of the Ming dynasty (1606), Huang Ruliang advocated the repair of the tower, and the spire was rebuilt in the 58th year of the Qing Emperor Kangxi (1719). The tower has a height of 20.55 meters and is a five-story hexagonal pavilion-style masonry structure, which is covered with white lime earth. Each floor has six tower eaves, like an eagle fluttering. There is a giant gourd on the top of the tower, which points to the blue sky, ("Fig. 4"). Although the White Pagoda is a brick tower, the base of the tower is all made of stone. The tower is protected by stone railings, the inside of the tower is hollow, and there is a spiral ladder to go to the top of the tower. [19]

Fig. 4. Pictures of Ruiguang Tower before restoration.

B. *Ruiguang Tower restoration based on HBIM*

After the collapse of Ruiguang Tower's eaves in June 2014, the cultural relics protection department took relevant measures to protect the White Pagoda and its surroundings, but it still could not prevent the ruins of Ruiguang Tower. In order to prevent the tower's full collapse, the cultural relics protection department started to fully restore the tower. According to the "Design Plan for Emergency Reinforcement and Protection of Ruiguang Tower, Anping Bridge, Fujian Province" compiled by the Tsinghua University Architectural Design and Research Institute, the White Pagoda repair project will be based on the principle of "repairing the old as it is," strictly maintaining the original historical appearance of the building and restoring the healthy and complete state in the history of the ancient tower.

In view of the insufficient information of the drawing of the Ruiguang Tower, the project converted it into a model file based on the point cloud data obtained from the 3D laser scanning through data processing and import into Revit software; combined with the textual records and picture data in the survey data, a parametric model of the tower eaves was constructed; the integrity of the 3D data model of the Ruiguang Tower was achieved through HBIM technology, and the Ruiguang Tower was restored to its original state before damage ("Fig. 5"). In addition, some special-shaped components encountered in the repair process ("Fig. 6"), by extracting three-dimensional component models and combining 3D printing, can realize the manufacture of such components to meet the restoration needs.

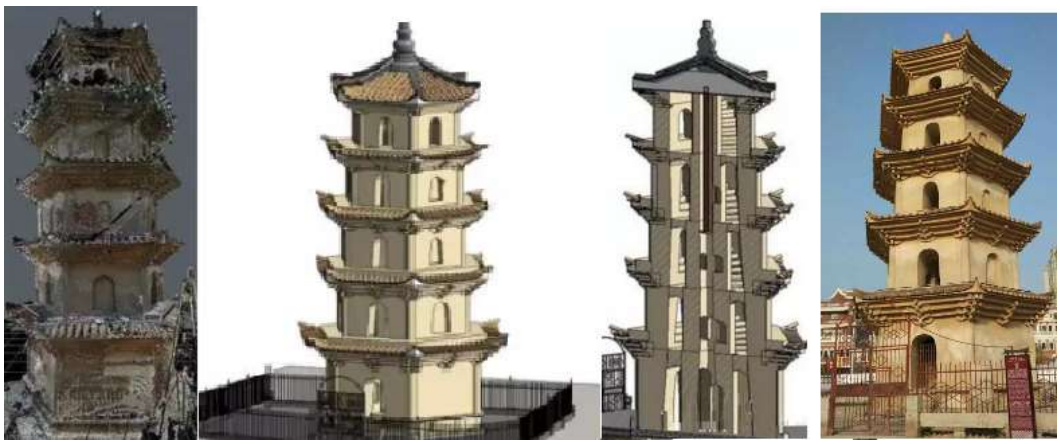

Fig. 5. Ruiguang Tower point cloud data model, Revit model, photos after restoration.

Fig. 6. Special-shaped component and its parametric model.

IV. CONCLUSION

The Heritage Building Information Model (HBIM) provides powerful technical support for the methods of heritage building restoration design, which makes the analysis and design of complex heritage buildings value and the carrier simple and easy. First of all, based on the thinking of the building information model (HBIM), the component information, structural information, material information, damage information, and repair methods of cultural relic buildings can be integrated into an interconnected logical system. When building beams, columns, walls, and roofs, , Door, window, and decoration models, the main characteristics information such as age, value, and damage have been loaded simultaneously. The final drawing is an expression of an information model in different dimensions, so that people in all aspects of heritage building restoration can simultaneously observe the restoration object in a 3D manner.

HBIM provides a new way of working; First, the management department, the protection unit, the designer, the construction party and the public are connected on a communication platform, so that all aspects of the protection work are closely linked, and coordinated management is carried out for coordinated management. Second, in the HBIM design process, valuable information can be permanently retained after the BIM modeling data is completed, which has the significance of establishing a new archive preservation method and retrieval method. The third aspect is the design of restoration construction, which can be implemented through BIM regulations, and the traditional construction techniques such as materials and structures can be reflected in the 3D BIM house restoration map. For cultural relics and ancient buildings, this method makes the diagnosis and treatment of diseases more straightforward.

Practice has shown that the application of HBIM is feasible in the field of heritage building protection, and it has initially demonstrated its great scientific and commercial value. At present, BIM technology is mainly used in the construction and design phase of heritage buildings. However, with the promotion and application of BIM technology and continuous improvement, it will be applied to the full life circle management of heritage buildings.

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