Design and Development of Heritage Building Information Model (HBIM) Database to Support Maintenance

Chen W., Yuan J., Luo H.
School of Civil and Hydraulic Engineering, Huazhong University of Science and Technology, China
weiya_chen@hust.edu.cn

Abstract. HBIM is an important and useful asset for historical building protection. It has significant advantages in the digital structured archiving of building structures and materials, which has been widely used and studied. This paper proposes a novel framework of HBIM database, which can be further divided into four parts: architectural status database, construction technique database, pathology database and featured element database. We integrated all kinds of data during the whole update process into the HBIM platform, and present in detail the content and organization of each constituting part. This HBIM database is timely updated and maintained to keep all information from the beginning to the end of the update process, so as to provide an important basis for better use and maintenance of historical buildings.

1. Introduction

Historical buildings are part of national history and an important carrier of cultural value, which is difficult to be recovered once damaged. Due to the long time span of historical buildings, many original design drawings and construction technologies have been lost, and it is difficult to determine their current status in term of structure safety. This brings great challenges to the renewal and maintenance of historical buildings. Although the Chinese government has proposed to strengthen the protection of historical buildings, a large number of them have lost their historical and cultural values in the process of renewal and maintenance during nationwide urbanization, which brings many challenges for the protection of historical buildings.

In order to solve the problem that the elements of historical features are damaged in the process of renewal and maintenance of historical buildings, digital and information technology is gradually adopted in this process. Building digital database to keep historical data in archives is one of the common methods for assisting the repair and protection of historical buildings at present.

As a basic tool in the AEC industry, BIM is the preferred tool to integrate building information from different sources, usually being used as an important approach of digital construction. Being a rich data repository of building facilities, BIM supports different tasks in the whole building's life cycle. Because there are special historical and cultural characteristics in historical buildings compared with general buildings, building information model technology for the special attributes of historical building protection is added on the basis of the technical core of BIM, and the concept of HBIM is born.

This paper proposes a framework of HBIM database, adding the historical and cultural attributes of buildings on the basis of the data information covered by BIM, and integrating various data in the whole process of historical building renewal project, so as to provide an important basis for the protection and repair of historical buildings.

The paper is structured as the following. Section 2 introduces the development process of HBIM theory and practice and the related work on how to build HBIM database. Section 3 introduces the HBIM database framework and its specific content proposed in this paper.

https://doi.org/10.7146/aul.455.c226

Section 4 takes a typical historical building in Wuhan named “Bagong house” as an example to show the HBIM database established in this paper. Finally, section 5 addresses the benefits, disadvantages, and delivers innovative recommendations based on the presented case study results.

2. Literature Review

2.1 HBIM Theory and Practice

For the theory and practice of BIM in the field of historical building protection, Arayici Y., Murphy M. and Fai S. had important research in the early stage.

From 2009 to 2017, Murphy M. and Mcgovern E. of the University of Dublin Ireland, took Henrietta street in Dublin as an example, putting forward the concept of HBIM (Murphy and Keenaghan, 2009), the technical framework of HBIM (Murphy and Mcgovern, 2009), the combined application of HIBM and GIS (Dore and Murphy, 2012), and how to convert BIM model data into a web-based game engine platform for popularization and use successively (Murphy and Corns, 2017).

Another major researcher is Fai S. (2013) from Carlton University in Canada, who mainly studies the application of BIM in cultural heritage information recording, and also has explored the process, implementation standards and application of achievements of HBIM.

Above all, the application research related to HBIM in recent ten years covers the basic concept, framework, construction process, combined use with other technologies and application promotion. However, in many cases, HBIM still stands as a tool for three-dimensional display of oblique photography and BIM, it can only be used for the auxiliary display of urban planning scheme and cannot reflect the specific historical information, let alone achieving further useful functions.

2.2 Establishing HBIM Database

Regarding the establishment of HBIM database, Zhou Hongbo (2017) puts forward the construction scheme of BIM database through the study of IFC Standard, and studies the methods of adding, modifying and deleting components in BIM component library. Sun Weichao (2012) explores the modeling idea of various components of ancient buildings on the Revit platform. From the perspective of the mapping relationship between knowledge ontology and HBIM, Shang Dunjiang (2021) proposes the HBIM data information structure based on 5W1H model for architectural heritage data information collection, and built an architectural heritage evaluation management framework based on HBIM-MR technology (MR refers to mixed reality). HBIM-MR is used to evaluate and manage architectural heritage through historical building information model data in virtual environment. Li Shujing (2014) proposes a new information collection method of "type tree + structure tree" for the information collection of cultural relics buildings, and tries to use BIM technology for the repair of these buildings.

As summarized above, most of the current research on HBIM database only focuses on a certain type of building data, such as building elements. There is relatively few research on the integration of different types and different stages of attribute data during the renewal of historical buildings.

In order to solve this problem, this paper proposes a framework of HBIM database to store more types of data, including building status, pathology, construction techniques and featured elements, which may be involved in the protection and repair of historical buildings.

3. Method

3.1 Establishment of HBIM Database

Conceptually, HBIM database is based on BIM with elements of historical features attached. To build HBIM multi-dimensional structured database, we need to identify and extract the historical feature elements of buildings, and keep their spatial structure. BIM is used to store these elements and bind them with time and space attributes in the next step. When the database is initialized, it will continue to evolve with the advancement of the renewal project.

Depending on the data source, the data collected are divided into four sub sections, which are as follows: element database, construction techniques database, pathology database and architectural status database.

The framework of HBIM database is shown in Figure 1.

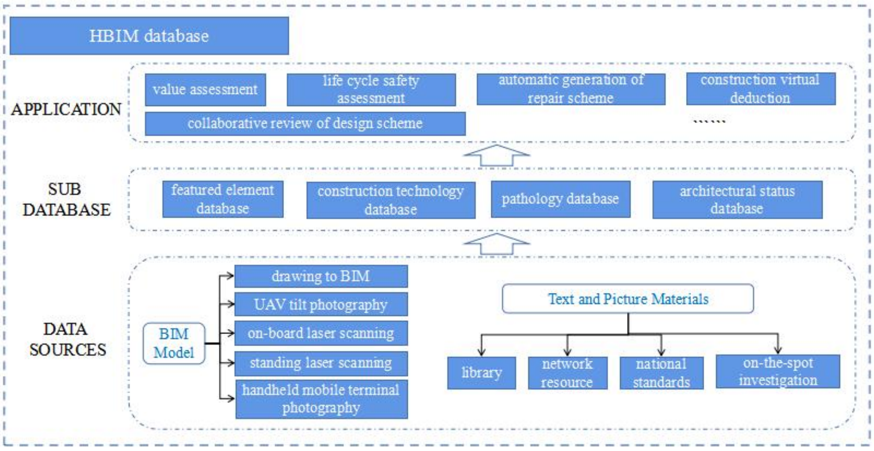

Figure 1: The framework of HBIM database.

3.1.1 Database of Featured Element

Building elements refer to the various elements of a building. For a historical building, its elements can always reflect the typical style characteristics of historical times. The element database is made up by information of featured elements of historical buildings, such as material properties, shape and size, design style, artistic features, etc., which can scientifically guide the construction, protection and repair of these elements.

In order to effectively store the featured element information of historical buildings digitally, the following three steps are taken to build the this database:

- Obtain the point cloud data reflecting the overall structure of the historical building and each featured element through laser scanner to build point cloud models.
- Fuse the overall point cloud model of historical buildings and the single point cloud model of each featured element to obtain the three-dimensional point cloud model of historical buildings.
- Transform the 3D historical building point cloud model into the corresponding BIM model, code different kinds of elements and give relevant attributes to form the

featured element database of historical buildings.

3.1.2 Database of Construction Technique

The construction technique database stores the construction and repair technologies used in the renewal of historical buildings, including repair construction technique standards and characteristic practices. In this database, the construction technique is divided into four types: special repair construction, building repair construction, structural repair construction and facility repair construction. Each type of construction technique is further subdivided according to the different repair contents. The repair of different parts of the building is described in detail from three aspects: current situation, repair objectives and technical measures. Finally, the establishment of the construction technique database is completed by collecting the text materials, videos and images of the repair construction process.

3.1.3 Database of Architectural Pathology

The building pathology in this paper refers to the combination of construction quality accidents and quality defects.

To establish a pathology database, firstly we divide pathologies into three categories according to the subjects as follows: building pathology, structural pathology and equipment pathology. And then the pathologies are further subdivided according to the location and manifestation of the pathology. The specific classification is shown in Figure 2.

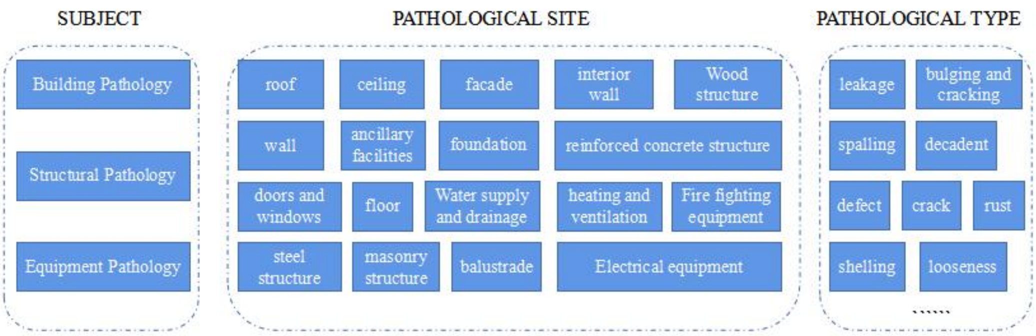

Figure 2: Contents in architectural pathology database.

Finally, a pathology database is established, which contains the information of pathology types, pathology distribution, pathology formation mechanism and deterioration mechanism, etc. All data are derived from architectural pathology and the real conditions of historical buildings obtained on site.

3.1.4 Database of Architectural Status

The architectural status database collects and summarizes various data of historical buildings to provide a strong guarantee for surveillance and repair. At the same time, it also serves as basic data to assist in generating planning schemes for building renewal and utilization. Data in the current database includes the material of a single historical building: geographical location, block overview, building overview, historical evolution, preservation value, design documents, four-dimensional model, drawing information, etc. At the same time, it also includes the current laws, regulations and standards related to the preservation and repair of historical buildings.

These data come from historical building preservation plans, relevant records on the network, national codes and standards, and data collected on site. The database sets up a series of architectural attributes to structure and integrate these scattered data from different sources for reference for subsequent preservation and repair.

3.2 BIM Modeling in Complex Scenes

3.2.1 With Design Drawings

When there are mapping drawings of historical buildings, the method of "drawing to BIM" is used. "Drawing to BIM" is to convert an existing 2D architectural drawing to a 3D model, which is based on the architectural information given on the architectural surveying and mapping drawings, and directly constructs the three-dimensional model in a BIM software such as Revit.

3.2.2 Without Design Drawings

When there is no mapping drawing of historical buildings, we need to take different methods to obtain drawings according to the different scales and accuracy that are to be measured. Generally, we adopt four mapping methods: UAV tilt photography (for a wide area), mobile laser scanning (for indoor complex space), terrestrial laser scanning (for near ground space) and handheld mobile terminal photography (for featured elements) according to the different scope of application.

4. Case Study

4.1 Architectural overview

Bagong house is one of the first-class excellent historical buildings in Wuhan, located in the Russian concession of Hankou. It is a Renaissance building with brick concrete structure, and is designed by Jingming foreign firm, a British funded company.

Figure 3: "Xiao Bagong House" and "Da Bagong House" in 2015.

4.2 BIM Modeling

The BIM model of Bagong house is generated by the method of "Drawing to BIM", and the modeler manually constructs the BIM model in Revit software according to the data of scanned two-dimensional architectural drawings. Then, the modeler renders the BIM model to make it more in line with the architectural reality, and finally integrates the rendered model into the platform.

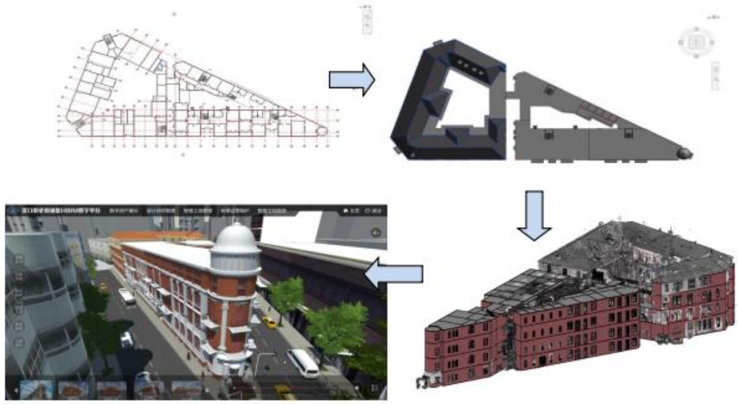

Figure 4: BIM modeling process of "Bagong House".

4.3 HBIM Database of Bagong House

4.3.1 Featured Element Database

The identification of featured elements of Bagong house is mainly based on the contents of historical building protection plans. For example, the railing in Figure 5 is the key protection part specified in the plan. Through the description of the current situation in the plan, it can be seen that the style, shape and decoration of the component have certain historical and artistic value, which can reflect the construction style of Jingming foreign firm, the builder of Bagong house at that time to a certain extent. Therefore, the component is regarded as one of the featured elements of Bagong house, and put it into the featured element database.

Figure 5: Stair handrail of "Bagong House" (Current situation: the handrail column capital is exquisitely carved, the body of the column is carved with petal decoration, and the top is pumpkin shaped. The right column also has bowl decoration above the pumpkin shape).

After determining which components are the featured elements we need, laser scanner is used to obtain the point cloud data of the elements, and then the 3D model of the elements is obtained. Then the 3D model of elements and attribute information (such as name, distribution, current situation, material, size, etc.) are collected for coding. Repeat the above operations for all featured elements to make a collection, and you can get the featured element database of Bagong house, as shown in Figure 6.

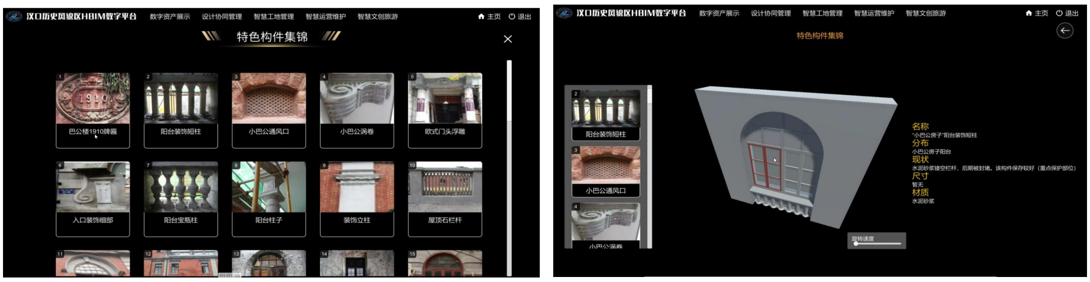

Figure 6: Snapshot of featured element database of "Bagong House".

4.3.2 Construction Technique Database

The repair of different parts of the building is described in detail from three aspects: current situation, repair objectives and technical measures. Some repair technologies with special requirements are also recorded in the database. As shown in Table 1, take the repair measures of grass reinforced gray floor as an example.

Table 1: Repair measures of grass reinforced gray floor.

Three aspects	Concrete content	Status picture
present situation	The floor of the indoor toilet and kitchen of Bagong house is grass reinforced ash leveling floor, that is, straw stems are added to the "foreign ash", which can increase the tensile force and ductility of the ash and prevent wall cracking.	
repair target	After the repair of Bagong house, it is mainly used for office and boutique hotel. The toilet function is still used and floor tiles are used.	
technical measures	The grass reinforced gray floor has serious damage problems such as exposed reinforcement, corrosion of reinforcement, serious carbonization and pulverization of cement, which can be removed and rebuilt according to the actual situation of the site. For the floor slab that does not meet the demolition conditions, the method of external bonding carbon fiber shall be adopted for reinforcement.	

In order to more intuitively describe the repair technique, we recorded the complete repair technique as a video at the construction site and also stored it in the construction technique database, so as to provide reference for the future repair of the building or the repair and renewal of other historical buildings.

4.3.3 Architectural Pathology Database

The pathology data of Bagong house are mostly from the protection plans of historical buildings and on-site shooting. We classify the pathology data of Bagong house according to the previously divided pathology types, and fill these data into the corresponding types for detailed description (including picture description and text description), as shown in Figure 7.

Figure 7: Snapshot of pathology database of "Bagong House" (Classify the pathologies existing in "Bagong house" according to the classification standards, and store the pathology data in the database. Click the pathology name in the list on the right to view the corresponding photos, coordinates, disease description, etc).

4.3.4 Architectural Status Database

For the architectural status database of Bagong house, we firstly make a template according to the relevant attributes of historical buildings, and then filled the text or image data obtained from various ways into the template according to a certain format, so as to complete the structure of the data for computer search and use.

Figure 8 shows the current situation of Bagong house in HBIM database.

Figure 8: Snapshot of architectural status database of "Bagong House".

5. Conclusion

Digital archiving of historical building materials is an urgent need at present. The HBIM database framework proposed in this paper integrates the current situation, featured elements, repair technique and pathology of historical buildings, and comprehensively integrates the data that may be needed in the renewal project of historical buildings and stores them in a BIM model. Different from the traditional building management using BIM model, it deeply excavates the unique historical and cultural elements of historical buildings, which can effectively reflect the heritage value of the building to a certain extent, and can continuously record the historical building data and assist its operation and maintenance during the process of heritage preservation and utilization.

However, the current HBIM database still faces some limitations. Although the database stores a large number of construction data from various sources, there may still have data loss and errors due to the limitations of manual collection. Therefore, more intelligent means should be considered to improve the process of data collection in the future.

Funding

This work was supported by NSFC under Grant 72001086.

References

Murphy M., Keenaghan G., Mcgovern E., (2009). A Flexible Web Based Learning Tool for Construction and Surveying Students Using Building Information Modelling and Laser Scanning.

Murphy M., Mcgovern E., Pavia S., (2009). Historic building information modelling (HBIM). pp.311-327.

Murphy M., Mcgovern E., Pavia S., (2012). Historic Building Information Modelling - Adding Intelligence to Laser and Image Based Surveys. ISPRS-International Archives of the Photogrammetry. Remote Sensing and Spatial Information Sciences, pp. 1-7.

Dore C., Murphy M., (2012). Integration of Historic Building Information Modeling (HBIM) and 3D GIS for recording and managing cultural heritage sites: International Conference on Virtual Systems and Multimedia.

Murphy M., Corns A., Cahill J., (2017). Developing Historic Building Information Modelling Guidelines and Procedures for Architectural Heritage in Ireland, pp. 539-546.

Fai S., Sydor M., (2013). Building Information Modelling and the documentation of architectural heritage: Between the 'typical' and the 'specific, International Journal of Dermatology. pp.705-710.

Zhou H., (2017). Research on BIM component library based on IFC Standard. JOURNAL OF GRAPHICS, pp. 589-595.

Sun W., (2012). Design of ancient building information model system based on Revit architecture． School of architecture, Tianjin University.

Shang D., Xu B., (2021). Application of HBIM-MR technology in architectural heritage evaluation and management from the perspective of Ontology. Construction economy, pp. 93-97.

Li S., (2014). Collection and expression of architectural heritage information based on BIM Technology under the background of information surveying and mapping． School of architecture, Tianjin University.