Application of 3D Information Expression Method of Ancient Buildings Based on Point Cloud Data and BIM

Li Wang1,*

1Taishan University, Tai’an, 27100, Shandong, China

*Corresponding author e-mail: wangli@tsu.edu.cn

Abstract. Recently, with the continuous development of technologies such as smart cities and virtual reality, the demand for 3D geospatial data is also growing. 3D laser scanning technology can be used to collect 3D geospatial data, create 3D scenes and collect other data to obtain outstanding Visual effects and scalability. This article puts forward the application research of ancient architecture three-dimensional information expression method based on point cloud data and BIM. Using 3D point cloud modeling and surface reconstruction of 3D point cloud data, in the form of a grid of a given point cloud, a 3D point cloud modeling is used to reconstruct a 3D model based on point cloud data and perform surface reconstruction of 3D point cloud data. The 3D digital protection of ancient Chinese buildings is an important way to inherit the essence of Chinese architecture. It helps to record the structural shape and historical, cultural and scientific value of ancient buildings, and provides accurate data support for the maintenance and repair of buildings. Accurate data support for building repairs and maintenance has improved the accuracy and visibility of information by 50% for the protection of ancient buildings.

Keywords: Point Cloud Data, BIM, Modeling, Surface Reconstruction

1. Introduction

1.1. Background and Significance

The unique style of ancient Chinese architecture occupies an unprecedented position in the history of world architecture. It also has important reference significance for introducing scientific research and artistic creation. However, due to various reasons such as history and economy, many ancient buildings have also been destroyed, and some ancient buildings have gradually disappeared from people's vision [1-2]. It is becoming more and more urgent to protect old buildings, but the lack of manufacturing methods and technologies for old buildings and the lack of experts for protecting old buildings make it more and more difficult to protect old buildings [3]. Traditionally, text documents and photos are used for description, so it is very important to find new ways to protect old buildings, because historical documents and other methods can no longer guarantee the protection of old
buildings[4]. Three-dimensional point cloud modeling and surface reconstruction of three-dimensional point cloud data, in the form of a grid of a given point cloud, are obtained using 3D point cloud modeling to reconstruct a 3D model based on point cloud data and perform surface reconstruction of 3D point cloud data. This helps to protect, repair and rebuild old buildings [5]. Therefore, it is very important to apply point cloud data and data obtained by BIM technology in the three-dimensional information of ancient buildings.

1.2. Related Work

Wen MH believes that the establishment of the quaternion method lays the foundation for the establishment of point-to-point set registration theory and algorithms. It is believed that the point-to-point set adjustment algorithm can effectively solve the actual engineering registration problem. The man-made damage to old buildings will cause various types of natural environments[6]. Therefore, deformation monitoring is needed to monitor the extent of this damage. Regardless of whether sensors or other monitoring methods are used, stations need to be set up. The second data comparison gives the deformation law, so active measures can be taken to reduce the damage caused by deformation [7]. Ancient buildings have been exposed to the wind and sun for a long time, and the degree of damage will vary. In order to accurately determine the degree of damage, it is necessary to investigate, draw graphics and manage the protection of ancient buildings. Wodak S J believes that the protection surveying and mapping process of old buildings is unique, and it is necessary to do a good job of protecting the building to prevent damage during the surveying and mapping process. Investigators and drafters must adopt a serious and responsible working attitude [8-9]. However, their research is not accurate and comprehensive enough. The application research of the three-dimensional information expression method of ancient buildings based on point cloud data and BIM in this paper is more accurate and comprehensive [10-11].

1.3. Main Content

The innovation of this thesis is to learn point cloud data and BIM technology courses, and analyze the application of the three-dimensional information expression method of ancient buildings based on point cloud data and BIM. Space division divides the minimum bounding box of point cloud data into multiple spaces Smaller cubes, and then simplify the points set in each small cube according to the deletion criteria. According to various simplified standards, it is divided into average distance method, uniform grid method and 3-axis cutting method. The average distance method uses a point as the center point and deletes all points in the cube that are less than the average distance to the point.

2. Application Research Method of Ancient Architecture Three-Dimensional Information Expression Method Based on Point Cloud Data and Bim

2.1. AHP

Use Analytic Hierarchy Process (AHP) to obtain distance, time cost and satisfaction weight. In the 1970s, when US operations researcher Say became the subject of a Pentagon survey, he proposed a hierarchical model with multiple planning and decision analysis. This will divide some decision-making elements into target level and reference level, qualitative and quantitative analysis, rather than project level. The main steps:
The first step: establish a hierarchical structure;

Establish the target layer, the criterion layer and the scheme layer, and obtain the hierarchical structure diagram;

Target level: According to the preferences of tourists, suitable ancient buildings will be selected as the highest element;

Criterion level: It is necessary to reasonably analyze the relationship between the elements of each criterion level to see whether they belong to the same level relationship or the subordination relationship.

Those belonging to the same level relationship are at the same criterion level, and those belonging to the subordination relationship must establish a lower level of criterion;

Solution level: The solution to the problem is taken as the bottom factor.

Step 2: Construct the judgment matrix and assign values

Construction of the judgment matrix: The first element of the judgment matrix takes the element with the downward subordination relationship, compares the two, and then obtains the required importance scale according to the level of importance.

Let the judgment matrix be \( A = (a_{ij})_{n \times n} \), the judgment matrix has this property:

\[
a_{ii} = 1; a_{ji} = \frac{1}{a_{ij}}; a_{ij} > 0
\]  \( \tag{1} \)

2.2. Laplace Filtering Algorithm

Laplace is also a relatively simple and very popular algorithm for eliminating point cloud noise. The main principle is to use the Laplace operator for all points in the 3D point cloud model. The 3D point cloud denoising algorithm is based on sub-bass, basically using high-frequency geometric noise energy to distribute to other points near the point, that is, through a continuous process. Move the point to a nearby center to achieve the goal of iteration and gradual noise reduction. Laplace's expression formula is as follows:

\[
\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}
\]  \( \tag{2} \)

For uniformly distributed 3D point cloud data, the Laplacian denoising algorithm usually provides relatively ideal results. For point cloud data with uneven distribution or too large noise points, the center of the local neighbor is usually the same as the center of the neighbor, but the domain center is different. At this time, the denoising of the Laplace filter algorithm moves the current point away from its original position, thereby moving it to a higher point cloud data density. This is the cause of functional wear and tip drift after several iterations.
3. Application Research Experiment of Ancient Building Three-Dimensional Information Expression Method Based on Point Cloud Data and Bim

3.1. Point Cloud Data Experiment

3D laser scanning is increasingly being used as a new technology, and architecture-based applications are mainly old building protection and digital 3D simulation. This experimental study uses laser point cloud processing to create drawings and actual 3D models. In this experiment, based on the recorded 3D point cloud, the size, model, color, and attribute information of the relevant building feature components are recorded, and the old requirements of building measurement and mapping starting from point 3 are combined. The accuracy of the recorded point cloud meets the requirements.

Instrument error is inevitable, including ranging error and angle measurement error. The error formula is as follows:

$$m_y = \sqrt{m_d^2 + \frac{m_{\alpha}^2 \cdot S^2}{\rho^2}}$$

(3)

Among them, $m_\alpha$ is the error in the distance measurement of the instrument, this time using non-prism measurement, so $m_d=2\text{mm}$, $m_\alpha$ is the error in angle measurement, $m_\alpha=1^\prime$, $S$ is the distance between the measuring point and the measuring point, $\rho=206265^\prime$ , The data results are shown in Table 1:

|                | $\rho_1$ | $\rho_2$ | $\rho_3$ | $\rho_4$ | $\rho_5$ |
|----------------|---------|---------|---------|---------|---------|
| Horizontal distance (m) | 11.621  | 15.979  | 8.731   | 8.466   | 11.479  |
| Instrument error (mm)    | 2       | 2       | 2       | 2       | 2       |

Alignment error The alignment error will affect the angle measurement accuracy and thus the point position accuracy. The error formula is as follows:

$$m_z^2 = \frac{5D^2}{2D_0^2} \cdot m_1^2$$

(4)

Among them, $m_1$ is the alignment error of the optical plummet, $D$ is the horizontal distance between the measuring station and the measuring point, and $D_0$ is the horizontal distance from the measuring station to the backsight point. Generally, the optical centering error will not exceed 5mm, and the value of $m_1$ is 5mm. The data results are shown in Table 2:
### Table 2. Instrument alignment error

|       | ρ1      | ρ2      | ρ3      | ρ4      | ρ5      |
|-------|---------|---------|---------|---------|---------|
| D (m) | 11.621  | 15.979  | 8.731   | 8.466   | 11.479  |
| D0 (mm)| 19.917 | 33.551  | 30.381  | 16.157  | 34.575  |
| mz (mm)| 5      | 4       | 3       | 4       | 3       |

3.2. **Construction of Traditional Model of Ancient Architecture**

The point cloud model created by processing precise point cloud data from 3D laser scanning technology has unparalleled advantages. It represents the current model of the old building model, but also represents the point cloud model that contains property information such as buildings. In addition, other engineering methods or means should be used to analyze and express the architectural heritage, including data structure, aging, deformation, damage and special trace intervention processes. The BIM platform allows you to visualize model parameter models and integrate information storage. Therefore, using BIM technology to create 3D models and parameterize them to represent attribute information (such as element sizes and materials) is very important for studying the structure and intrinsic value of old buildings.

4. **Experimental Data Analysis**

4.1. **Preliminary Streamlined Comparison Experiment of Point Cloud**

Preliminary simplified comparison can execute mesh-based simplification algorithms faster, reduce the amount of point cloud data, reduce the number of triangular patches generated during post-reconstruction work, and effectively improve the efficiency of 3D display. The point cloud is rationalized and improved and suitable for the initial stage. The simplified experimental results of this article for words and rabbit point clouds are shown in Figure 1:
Points before simplification
Simplified points

Figure 1. Simplified result of horse point cloud

Through the three-dimensional laser scanning technology, the processed high-precision point cloud model can express the real status information of ancient buildings, and plays a decisive role in the retention and display of three-dimensional information of ancient buildings and overall monitoring. The three-dimensional model constructed through BIM technology can record and count the attribute information, which is convenient for the three-dimensional information management and information sharing of ancient buildings. Especially in the field of architectural heritage protection, point cloud data can make up for the lack of drawings in the construction of the ancient building BIM model. The BIM model provides an important means for attribute information management. Data is shown in Figure 2:
It can be seen from the comparison results that the method of simplifying the accuracy of the normal and the method of simplifying the curvature scanning can fully retain the contour and area information of the point cloud model in the geometric features of the point cloud model, and will solve the vector for multiple calculations. According to the grid in this article, the execution time can be increased by replacing other points in the grid with the center of the grid, depending on the proximity of the point cloud position in the space, and find the closest adjacency bounding box method. Parts that undergo major local changes will lose functional information, but it is useful for preliminary simplification of the point cloud.

4.2. BIM Experiment Comparison

The construction of BIM models based on point cloud data is feasible, especially in the field of architectural heritage protection. Point cloud data can make up for the lack of drawings in the construction of ancient building BIM models. BIM models provide important means for attribute information management. This time, 10 side lengths were selected and measured on the BIM model, and then compared with the corresponding data measured by the vernier caliper. The measured length values are shown in Table 3.

Table 3. Comparison of results between BIM model and manual measurement parameters

| Measurements | BIM model | Manual measurement | Gap     | Relative error(%) |
|--------------|-----------|--------------------|---------|-------------------|
| S1           | 263.71    | 270.05             | -6.34   | 2.35              |
This paper analyzes and analyzes the experimental data and combines the advantages of modern digital protection technology in the field of ancient building protection, and proposes an effective expression method of ancient building information based on three-dimensional laser scanning technology and building information modeling (BIM) technology. An example has realized the establishment of a BIM model based on point cloud data to express the life cycle information of an ancient building, which verifies the feasibility of the method.

5. Conclusion

By using CAD software, the modeling and management of the 3D point cloud becomes very easy, especially from the perspective of role management and management, which can save time and save the trouble of converting operator data in actual applications. The data is well managed, and 3D landscaping plays an important role in displaying and managing soil data in new ways in urban planning, landscaping, traffic management, and tourism. Build a BIM model based on cloud data, which represents the life cycle data of old buildings, to see the feasibility of this method. This consensus method can provide important information for digital preservation, system representation and scientific management of architectural culture. All in all, the application of the three-dimensional information expression method of ancient buildings based on point cloud data and BIM researched in this paper has high economic value.

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