

Research on 3D Laser Scanning Reconstruction of Ancient Buildings Combined with BIM Technology

Ensheng Liu*, Chunyong Luo, Chunbaixue Yang, Yuhua Huang

College of Building Engineering, Jinggangshan University, Ji'an, China
Email: *1410893@tongji.edu.cn

How to cite this paper: Liu, E.S., Luo, C.Y., Yang, C.B.X. and Huang, Y.H. (2023) Research on 3D Laser Scanning Reconstruction of Ancient Buildings Combined with BIM Technology. *Journal of Computer and Communications*, 11, 233-240.
<https://doi.org/10.4236/jcc.2023.117015>

Received: June 28, 2023

Accepted: July 28, 2023

Published: July 31, 2023

Abstract

After more than 30 years of scientific and social development, surveying and mapping technology by leaps and bounds, engineering surveying technology has undergone tremendous changes. In the process of protecting ancient buildings, it is necessary to obtain the precise dimensions of architectural details. In this study, the path of 3D laser scanning combined with BIM technology is explored. Taking the observation and protection of the ancestral hall of the Liu family as an example, this study aims to draw drawings that reflect the relevant information about the ancient buildings, the accurate three-dimensional model of ancient buildings is established with BIM technology, which provides new methods and ideas for the research and protection of ancient buildings.

Keywords

Liu Ancestral Hall, 3D Laser Scanning Technology, BIM Technology, Point Cloud Processing

1. Introduction

With the passage of time, the ancient buildings built by the ancestors gradually show their potential historical value and cultural value. Or due to the long age, their own structure and materials are lost, or due to the loss of the traditional construction technology of ancient buildings and the decline of culture, these ancient buildings are damaged to varying degrees, and then in the process of modern urbanization, gradually replaced by modern tall buildings. Ancient buildings reflect the history of a country, and a country that does not respect history cannot develop quickly and well. Therefore, the protection of ancient buildings

and the cultural value contained in them is an important task facing various cities at present. Complete drawing data is the key to the reinforcement and repair of ancient buildings. At present, a large number of existing data on ancient buildings cannot meet the requirements of repair [1]. In view of this, according to the different architectural structures, architectural shapes, artistic styles and so on, it is more and more become the future development trend to use 3D laser scanning technology and BIM technology to combine the restoration and protection of ancient buildings. This design takes the Liu ancestral hall (as shown in **Figure 1**) in Wenshi Village, Jizhou District, Ji'an City, Jiangxi Province as the observation object, the observation task of the Liu ancestral hall adopts three-dimensional laser scanning technology to conduct data collection, and then analyze and process multiple sets of data observed by BIM technology, so as to choose reasonable reinforcement and protection measures.

2. Modeling and Drawing Output of Liu's Ancestral Hall Combined with BIM Technology

Three-dimensional laser scanning systems according to different operation positions can be divided into four types: airborne laser scanning system, ground laser scanning system, handheld laser scanner and special application of laser scanner, the ground 3D laser scanning system is widely used, it is mainly composed of 3D laser scanner, power supply system, computer control unit, support and system supporting tools [2]. 3D laser scanner is the main component of 3D laser scanning system, which mainly consists of timer, laser pulse transmitter, laser receiver, scanning system, control system and other auxiliary function systems [3] [4].

The Liu ancestral hall covers an area of more than 900 square meters, with two Wells and three steps, three open porches, and five wide faces. There are two red stone lions in front of the ancestral hall, majestic and solemn, as if guarding the ancestral hall and defending the honor of the Liu family [5]. Although the exterior of the general temple has experienced many vicissitudes of life and



Figure 1. Liu's ancestral hall.

carved the traces of the passage of time, it is still solemn and solemn today, adding a bit of majesty. With the passage of time, the damage of ancient buildings and their wooden components is more and more serious, or due to the long age, their own structure and materials are lost, or due to the loss of traditional construction technology of ancient buildings and the decline of culture, these ancient buildings have been damaged to varying degrees. This paper introduces the application in the restoration and protection of ancient buildings based on the ancient of Ji'an, and the combination of three-dimensional laser scanning technology and BIM technology.

1) Data Acquisition

Under good meteorological conditions, relevant personnel were organized to conduct a site survey of the Liu ancestral hall, and understand the actual situation of traffic, vegetation distribution, buildings and structures of the Liu ancestral hall in advance, so as to form a general architectural outline and impression, and facilitate the measurement preparation and the later drawing work. After site found the overall layout of lee ancestral hall dwellings range is larger, may have great influence on the integrity of laser scanning data and also may produce data redundancy, so in order to choose an economic, efficient and reasonable measurement route need to set up multiple sites from multiple angles, so as to get the complete scanning data, so the indoor and outdoor set up scanning site 10.

When carrying out the measurement work in a certain measurement area, first of all, a more rigorous method and more sophisticated instruments should be used to determine the coordinates of a small number of control points distributed in the whole area, as the framework and basis of mapping or construction lofting, to ensure the overall accuracy of the measurement area, which is called the control measurement [6].

2) Point Cloud Data Processing

The laser scanner used this time is a FARO Focus 3DX130-type three-dimensional laser scanner. The three-dimensional laser scanner is set up on the arranged scanning site, sets the relevant parameters of the instrument, and the instrument carries out three-dimensional scanning of the ancient building and automatically collects the point cloud data.

The specific work is as follows:

a) After setting the relevant parameters, turn on the machine, the laser scanner is started, and then the instrument automatically starts to scan the surrounding buildings. In this process, the details of component texture information are obtained with the handheld 3D laser scanner [7] [8].

b) After obtaining the image information, the instrument will automatically complete the selection of the 3D coordinates of the building, and the obtained point cloud data will be stored in the scanner file, and the point cloud data file can be exported by using USB or external laptop. Next, we need to de-noise (as **Figure 2**) the point cloud in order to build the current status model of the ancient architecture.

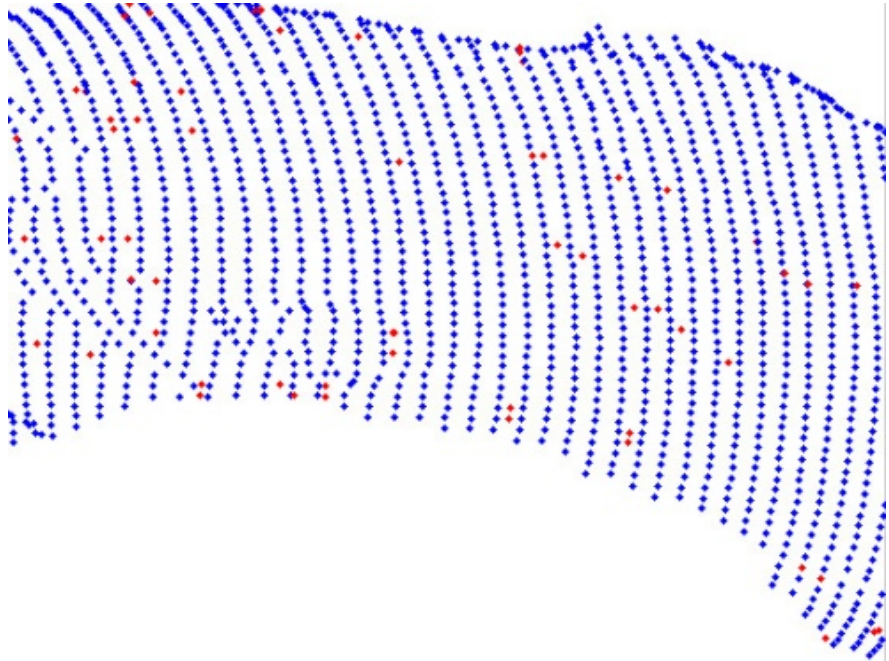


Figure 2. Point cloud denoising on column surface.

These points have information about 3D coordinates (X, Y, Z), laser reflection intensity, and color (RGB), which together create a recognizable 3D structure [9]. But due to the point cloud data is large, the number of hundreds of thousands, and there are errors and noise defects, therefore, must before the point cloud data analysis treatment, remove the scanner due to itself and the surrounding environment of noise and irrelevant, so you can avoid data redundancy, greatly convenient results production as **Figure 3**.

In the operation of the three-dimensional laser scanner, the scanning object is too large and complex. At this time, the single-station scanning often cannot complete the comprehensive and complete data collection of the scanning object, and it is necessary to scan with multiple stations to complete the complete data collection of the scanning object. The multi-station scanning data reflects the form of the collected scanning object, and cannot reflect the scanned object completely. At this time, it is necessary to use professional point cloud processing software to assemble the scanned multi-segment point cloud data (also called point cloud image registration) to get the complete scanning data of the target object. There are four main methods of point cloud splicing: automatic splicing; manual splicing; splicing based on measurement points; mixed splicing.

When a 3D laser scanner is used to scan the target, the observation site may be affected by the scanning equipment, surrounding environment, human interference, etc., which will have some noise points, and the collected data will be unable to accurately describe the spatial location of the scanned object. Point cloud denoising is the removal of point cloud data and error point unrelated to the measured point object in the original point cloud [10].

Point cloud data acquired by 3D laser scanning technology has the advantage



Figure 3. Data acquired with a 3D laser scanner.

of precision and dense; but also highly redundant, discrete and scattered distribution. After the point cloud splicing of Liu ancestral hall, the complete point cloud data is more than 10 million points. In order to improve the efficiency of computing, it is necessary to simplify and smooth the of point cloud data to some extent [11].

3. Point Cloud Processing and Study Object Modeling

In the point cloud processing software, convert the ancient architecture point cloud data format to the document in XYZ format [12]. Using CAD professional drawing software to set the basic drawing environment, select the appropriate proportion, according to the characteristics of the point cloud data extracted structure, according to the features with size, three-dimensional coordinate information draw the Liu ancestral hall feature line (axis line, wall line, doors and Windows line, etc.), and further with CAD draw Liu ancestral hall plan, elevation and other two-dimensional plane features, provide necessary repair construction key data.

The corresponding construction name and size are marked on the characteristic map of the Liu ancestral hall, including the outer wall, inner wall, load-bearing column, beams, doors and Windows, platform base and main body of the Liu ancestral hall. On this basis, this data information can be used to model the Liu ancestral hall through Revit modeling software.

The characteristic drawings of the Liu ancestral hall plan and elevation drawings are imported into Revit software. Using the modeling function of the software, the external wall, inner wall, load-bearing beams, doors and Windows, steps, and roofs of the Liu ancestral hall are drawn, so as to build a three-dimensional simulation model of ancient dwellings. Later, the rendering function of the software was used to render the ancient dwellings of Liu ancestral hall and give them texture and map. Finally, the exquisite three-dimensional model can be obtained [13] as **Figure 4**.

Eight characteristic points were selected in the obvious positions such as the



Figure 4. Renderings of point cloud splicing of Liu ancestral Hall.

gate, exterior wall, corner and intersection of the ancient residence of Liu ancestral Hall, and then the three-dimensional coordinates of these characteristic points were measured with measuring instruments, and compared with the coordinate values obtained in the three-dimensional simulation model.

The accuracy of the phase type 3D laser scanner is higher than that of the pulse type. The instrument model used in the experiment is Faro3DX130, the measurement speed is 976,000 points/second, the maximum scanning range is 330 m, the ranging error is 2 mm at 20 m, and the noise error is 0.3 mm. The nominal data meet the scanning accuracy requirements of the Lee ancestral hall, and the 3D coordinate difference of the measured building points is within 4 mm, and meet the requirements of the nominal accuracy of the instrument.

4. Analysis of the Protection and Utilization of Ancient Buildings

Through in-depth investigation and research of the ancient dwellings of Liu Ancestral Hall, it is found that there are quality problems in its own structural materials, roof and roof brick technology, water leakage and waterproof of the building itself, and the color of the exterior wall. The details are as follows:

The common problem of most ancient wood structures is that the main structure of the building is wood, but due to the long damage of wood and the huge consumption of wood on the market in other fields, there are not a large number of available woods suitable for the ancient buildings [14]. At present, there is a shortage of wood in the market. Under the national policy of advocating saving wood and protecting the forest, it is more difficult to choose the right dry wood. Therefore, the supply and quality of wood cannot be guaranteed in the short term.

With the rapid development of modern society, ancient buildings including other modern buildings of observation technology are also in rising, reinforcement treatment is varied. The use of modern high-tech means is conducive to the more comprehensive and more effective protection of ancient buildings. As the carrier of recognizing history and inheriting culture, the history and culture contained in ancient architecture carries the genes and blood of the Chinese na-

tion, which not only belongs to our generation, but also belongs to the future generations of [15].

Protect and identify the historical buildings in the village according to local conditions, and activate them on this basis, so as to integrate the ancient buildings into the urban and rural economic and social development. If conditions permit, the ancient building community can be built into a comprehensive cultural tourism project integrating various cultural tourism formats such as ancient town sightseeing, catering and food, research and exchange, so as to give full play to the cultural heritage and cultural value of ancient buildings [16] [17].

5. Conclusion

In this paper, the ancient village Liu ancestral hall for research and data processing object, using 3D laser scanning technology and BIM technology to complete the measurement of ancient buildings, data collection, can more realistic reconstruct the size of the building structure, and the late maintenance management to provide more detailed, more real data and detail construction features. Need to emphasize that by using the two technologies and combining with each other, well play the 3D laser scanning technology in ancient buildings, especially large-size residential data acquisition advantage, supplemented by BIM technology, through 3D simulation reconstruction, let all the construction of the participants to the real situation of ancient buildings have a clear intuitive understanding. We will further integrate VR technology to make conservation and reconstruction projects of ancient buildings more scientific and perfect.

Funding

Jiangxi University Humanities and Social Science Research Project 2022 (KG22101); Ji'an Guiding Science and Technology Plan Project (No. 621, 2022); Ph.D. Research Launch Project of Jinggangshan University (Natural Science) (JZB2209).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Fan, Y. and Shi, Y. (2015) BIM Combined with the 3D Laser Scanning Technology to Lead the Changes of the Design Industry in the Future. *Proceedings of the 4th International Conference on Information Technology and Management Innovation*, Atlantis Press, Dordrecht, 514-517. <https://doi.org/10.2991/icitmi-15.2015.84>
- [2] Zhang, L.W., Liu, P.F. and Li, G. (2017) Research on the Application of 3D Laser Scanning Technology in Ancient Building Mapping. *Beijing Surveying and Mapping*, No. z2, 68-72. (In Chinese)
- [3] Li, H.M., Zhang, C.Y., Song, S.Y., *et al.* (2020) Improving Tolerance Control on Modular Construction Project with 3D Laser Scanning and BIM: A Case Study of

- Removable Floodwall Project. *Applied Sciences*, **10**, Article 8680.
<https://doi.org/10.3390/app10238680>
- [4] Li, A.R., Deng, W.B. and Hou, X.Q. (2022) Application of 3D Laser Scanning Technology in Ancient Building Mapping. *Geospatial Information*, **20**, 101-103. (In Chinese)
- [5] Ma, H.Y. and Zhao, X. (2019) The Application of 3D Laser Scanning Technology and BIM Technology in the Protection and Mapping of Ancient Buildings. *Geotechnical Engineering*, **33**, 222-225. (In Chinese)
- [6] Liu, F., Zhu, S., Cheng, B.F., et al. (2019) Research on the Construction of Local Protection Evaluation System of Famous Historical and Cultural Towns and Villages in China—Taking Ji'an Area as an Example. *Journal of Jinggangshan University (Natural Science Edition)*, **40**, 82-88.
- [7] Liu, E.S., Cheng, X.J. and Huang, Y.H. (2019) 3D Scanning Fragment Reconstruction Exploration Using Artificial Fish Swarm Algorithm. *Surveying and Mapping Bulletin*, **4**, 137-140.
- [8] Liu, E.S., Cheng, X.J., Cheng, X.L., Zhou, T.F. and Huang, Y.H. (2020) Application of Three-Dimensional Laser Scanning in the Protection of Multi-Dynasty Ceramic Fragments. *IEEE Access*, **8**, 139771-139780.
<https://doi.org/10.1109/ACCESS.2020.3012438>
- [9] Yu, S.S. and Liu, R. (2022) Special Application of Three-Dimensional Laser Scanning Technology in the Protection and Restoration of Ancient Buildings. *Jiangxi Ceshui*, No. 2, 13-15. (In Chinese)
- [10] Yang, Z.W. (2020) On the 3D Scanning Technology and Its Application in the Reconstruction of the Qing-Dynasty Gable and Hip Roof Historical Building. *Cultural Relics of Central China*, No. 6, 137-141. (In Chinese)
- [11] Chen, C. (2022) Application of 3D Laser Scanning Technology in the Mapping and Filing and Structural Deformation Analysis of Ancient Buildings. *Geomatics & Spatial Information Technology*, **45**, 87-94. (In Chinese)
- [12] Song, X.J., Liu, Q.J., Gong, H.H., Zhu, L.M. and Zhou, D.L. (2022) Application of 3D Laser Scanning Technology in the Evaluation of Ancient Bridges. *Anhui Architecture*, **29**, 176-178. (In Chinese)
- [13] Wang, M. (2020) Research on the Restoration and Protection of Ancient Buildings Based on BIM Technology and Three-Dimensional Laser Scanning Technology. *Identification and Appreciation of Cultural Relics*, No. 8, 108-109. (In Chinese)
- [14] Cai, R. (2020) Application of 3D Laser Scanning Technology in Ancient Building Mapping. *Technology and Markets*, **27**, 89-91.
- [15] Zhou, M.C. (2021) Application of 3D Laser Scanning Technology in the Mapping and Drawing of Ancient Buildings. *Gansu Science and Technology*, **37**, 108-110. (In Chinese)
- [16] WanYan, D.J. (2020) Application of Deep Foundation Pit Support Technology Based on Big Data Analysis in Construction Engineering Construction. *Journal of Physics: Conference Series*, **1533**, Article ID: 042001.
<https://doi.org/10.1088/1742-6596/1533/4/042001>
- [17] Ying, C.L., et al. (2019) Applying BIM and 3D Laser Scanning Technology on Virtual Pre-Assembly for Complex Steel Structure in Construction. *IOP Conference Series: Earth and Environmental Science*, **371**, Article ID: 022036.
<https://doi.org/10.1088/1755-1315/371/2/022036>