Application of 3D Laser Scan Technology in the Surveying and Mapping of Ancient Buildings

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Abstract. Taking Wang's ancestral temple in Yongshan Town, Leping City, Jiangxi Province as the research object, through the teaching practice of surveying and mapping of ancient buildings, this paper summarizes the advantages and disadvantages of 3D laser scan technology in surveying and mapping of ancient buildings and discusses the Methods and approaches of combining industry-university-research cooperation mode in local colleges and universities under the background of cultural relics protection.

Keywords. Architecture of cultural relics, surveying and mapping of ancient buildings, 3D laser scan.

1. Introduction
As of December 2018, China has selected five batches of traditional villages. There are a large number of historical buildings and immovable relics in these villages, which need to be surveyed, studied and sorted out. In the guidance document for the evaluation of the professional education of higher education issued by the Ministry of Housing and Urban-Rural Development in 2017, the quality of education was clearly stated to be “familiar with the importance and basic principles of historical and cultural heritage protection and the use of existing buildings, and to be able to conduct architectural survey, mapping and preliminary conservation or renovation design”. At present, there are 298 colleges and universities with architecture in China, and the number of graduates reaches about 18,000 each year. This is an important force involved in the mapping and protection of ancient buildings. At the same time, it should be noted that traditional surveying and mapping requires a large amount of investment in human resources and time costs. Due to the serious shortage of architectural heritage protection professionals, it is difficult to effectively complete the corresponding basic work such as obtaining surveying and mapping data and drawings, and establishing records, which brings inconvenience to the protection and research work [1]. With the increasingly severe situation of cultural relics protection, it is necessary for local colleges and universities to carry out surveying and mapping teaching with new technology, new ideas and new methods.

This time we surveyed and mapped the historical buildings through the combination of the 3D laser scanning technology and the traditional manual mapping, and then analyzed the problems.

2. The Process and Problems of Traditional Manual Measurement
Surveying and mapping of ancient buildings is the only way to study, protect, maintain and build Chinese ancient buildings. Accurate and reliable data and correct information expression are the goals of surveying and mapping of ancient buildings. The earliest surveying and mapping event recorded in
ancient Chinese literature is Dayu’s flood control. The Historical Records describes Dayu’s “left level, right rule”.

“Zhun”, “sheng”, “gui” and “ju” are measuring tools commonly used since ancient times. [2] Since then, ancient China has made continuous innovations in measuring tools, and some fields even reached the advanced level of the world at that time. However, the history of China’s real use of Western surveying and mapping technology began in the 16th century when the western missionary Matteo Ricci came to China for exchange. Later, the Qing government set up more than ten schools, including Beiyang School of Surveying and Mapping, Baoding School of Surveying and Mapping, Beijing Army School of Surveying and Mapping and some local schools. Surveying and mapping gradually developed into an independent discipline. After the development of this period, the technical level in the late Qing Dynasty gradually changed from traditional surveying and mapping to modern surveying and mapping [3]. These surveying and mapping fields cover engineering, railway, mineral, water and other aspects, while for ancient architectural surveying and mapping, we have to mention the Chinese Construction Society established in the early 20th century. In the 16 years since its establishment, “many precious ancient architectural examples have been discovered and recorded, and thousands of surveying and mapping results have been completed, which laid a solid foundation for the framework of Chinese architectural history and became a brilliant starting point for the research and protection of Chinese architectural heritage” [3].

With the development of technology, the era of surveying and mapping based on manual surveying has quietly changed. Since the 1980s, total station measurement technology, close-range photogrammetry technology and 3D laser scanning technology have gradually occupied the main market of surveying and mapping, but the most promising technology is the 3D laser scanning technology at present. In short, no matter which kind of mapping technology it is, all are guided by the accurate and readable drawing and mapping results.

3. The History and Present Situation of 3D Laser Scanning Measurement

Since its entry into China in 2000, 3D laser scanning technology has been widely used in the fields of architectural heritage protection, virtual reality, deformation monitoring, medical and industrial measurement, and emergency services [4]. It continues to play an important role in ancient building surveying, cultural relics protection and recording.

In 2004, the Palace Museum and Beijing University of Civil Engineering and Architecture applied 3D laser scanning technology to the digital mapping of the ancient buildings of the Forbidden City, summarized and studied the methods and theories for processing 3D data. Finally, the relevant technical requirements for the collection standard, mapping content and expression form of 3D data of ancient buildings were put forward, and the specific implementation schemes of technical process design, data acquisition and processing were summarized [5].

In 2007, Tianjin University also used Tianbao 3D laser scanner to scan the Fengguo Temple Hall in Liaoning and the Summer Palace, etc., obtained the original data and carried out subsequent data processing research. To some extent, it summarized the status quo of ancient building surveying and mapping in China and proposed relevant solutions [6].

In 2014, Ding Yanhui from Beijing University of Civil Engineering and Architecture started with 3D laser scanning data, combined with manual mapping, discussed the application research of ancient building mapping and information management based on 3D laser scanning data, comprehensively elaborated how to apply 3D laser scanning technology to analyze the deformation of ancient building structure, wood structure modeling and data display, color record of ancient building and process records, etc. At last, he put forward a research model of ancient building survey and information management based on 3D laser scanning technology [7].

The above researches have elaborated and analyzed the 3D laser scanning technology in the ancient building mapping technical level, including how to establish the 3D information management system of the ancient buildings, the creation of the ancient building triangle network model, and the detailed process of the ancient building 3D scanning. Some articles also involve the superiority and inferiority of traditional mapping, as well as the superiority and the insufficiency of the 3D laser scanning
technology. However, it is the first time for Jiangxi ancient ancestral hall to use 3D laser scanning technology for surveying and mapping, and there is no discussion on the advantages and disadvantages of the combination of traditional manual surveying and 3D laser scanning from the perspective of teaching practice and drawing.

4. Field Mapping

4.1. Introduction to Wang’s Ancestral Hall
Wang’s ancestral hall, also known as wangzongwuci or zhaomutang, is located in Yongshan village, Leping City, Jiangxi Province (figure 1). There are more than 70 traditional buildings in the village, mainly in the architectural style of Gan school in Ming and Qing Dynasties. Wang’s ancestral hall, which is in the middle of the old street, is the physical witness of Yongshan’s history. The ancestral hall was built in Chongzhen period of Ming Dynasty. It has been renovated many times in modern times and is now used for important activities of clans. Wang's ancestral hall is the only stage relic of the Ming Dynasty in Leping. Its wood, brick and stone carvings are lifelike, with high cultural and historical value.

Figure 1. Wang’s Ancestral Hall in Yongshan, Leping City.

4.2. 3D Laser Scanning Operation
Wang’s ancestral hall is the object of this survey. The survey tools used include tape, steel ruler, plumb, hand-held laser rangefinder and 3D laser scanner. Auxiliary tools include vertical ladder, flashlight, card camera and UAV. Both methods of surveying and mapping are used. Among them, there are seven steps from 3D laser scanning point cloud data to CAD drawing.

- Understand the basic information of ancient buildings.
- Determine the location and number of mapping targets.
- Splicing point cloud data, optimize point cloud data, Import CAD.
- Combine with survey drawing, Conclusion analysis and comparison.

4.3. Intervention of Traditional Manual Measurement
Draw the plan, elevation and section with proper scale. The next step is to measure and to dimension the previously drawn sketch. For some ancient building components with special-shaped outline, it is too cumbersome to draw directly, so the author takes photos and videos of them. Sort out and check the mapping data, and use CAD to draw when the depth of the drawing is required.

4.4. Combination of 3D Laser Scanning and Manual Measurement
After the RISCAN PRO software completes the point cloud splicing, the point cloud model is presented in the view in the scale of 1:1 in CAD. Its spatial coordinates are repositioned, and the outlines of each facade, plane and other drawings are drawn by using the method of curving. The section can be roughly drawn. Because this model is composed of many points, only many points in dense arrangement can be seen when zooming, so its boundary is difficult to determine. And the point
clouds between different components overlap each other, so only the general outline can be described.

4.5. Mapping Results and Modeling

The results of 3D scanning and mapping, as well as the 3D scanning auxiliary drawing are shown in figure 2 and figure 3.

![Figure 2. Central Axis Profile of Wang’s Ancestral Hall from point cloud.](image)

![Figure 3. Central Axis Profile of Wang’s Ancestral Hall.](image)

The modeling steps of Wang’s ancestral hall are as follows.

1. Modeling of column foundation and platform foundation.
   Import CAD drawings into 3DMAX software, adjust the scale and establish the ground, patio and steps according to the measured elevation (figure 4).

![Figure 4. Plinth.](image)

2. Modeling of main structure
   The main building of Wang’s ancestral hall consists of purlin, beam and ground (figure 5, figure 6).

3. Roof modeling
   The camber of wing angle, the position of old angle beam and sub angle beam are accurately modeled with the help of roof aerial photos.

4. Wall modeling
   After the main wooden frame modeling is completed, the main facade and other three walls are established in the end. The main facade wall includes three door openings, wood carvings and plaques on the gate (figure 7).

![Figure 5. Shunfang.](image)

![Figure 6. Chuanfang.](image)

![Figure 7. Wall.](image)
4.6. Reflection on Manual Measurement and 3D Laser Scanning Mapping

4.6.1. Advantages and Disadvantages of Manual Mapping. Those advantages are presented as follows:

- The advantages of manual mapping are as follows:
  1. The measuring instrument is cheap and the tool cost is low.
  2. It has greatly trained the patience, basic skills and understanding of the mapping personnel.
  3. Surveying and mapping tools are portable, easy to get started and fast to use.

- The disadvantages of manual mapping mainly include the following four points.
  1. The surveyors directly contact with the ancient buildings, which is easy to cause secondary damage to the old buildings in disrepair. If the surveyors climb the mezzanine or roof of ancient buildings, it will cause some safety risks to them.
  2. The surveying and mapping time of complex ancient buildings is long and the mapping task is large. If the teaching time of surveying and mapping is limited, then the accuracy is difficult to be guaranteed. In addition, the internal joint mode of some mortise and tenon structures cannot be observed directly, which will bring difficulties to the sectional and detail drawing.
  3. To observe the ancient building components from the perspective of human will produce certain perspective effect, and all drawings are projection drawings, which will bring certain errors to the drawing.
  4. The angle of 3D direction cannot be accurately measured by ordinary instruments.

4.6.2. Advantages and Disadvantages of 3D Laser Scanning Mapping. The point cloud model obtained by 3D laser scanning technology is of great significance for ancient building surveying and mapping. Compared with traditional surveying and mapping methods, it has some advantages and disadvantages. Its advantages are mainly reflected in the following aspects:

- The first paragraph after a section or subsection heading should not be indented; subsequent paragraphs should be indented by 5 mm.

- Time is shortened and it can be reused in complex buildings. 3D laser scanning technology can collect point cloud data of the measured buildings in a short time, which greatly reduces the workload of surveying and mapping.

- Restore 3D information exactly. For the ancient buildings that are not easy to climb or the cultural relics that need to be protected, the data needed cannot be measured, only the possible structure can be figured out with the structure of similar ancient buildings, but the two-dimensional figure can be accurately drawn in the obtained model. And the drawing has no perspective error, and the shape and scale also maintain the effect of the building itself to the maximum extent.

- It is convenient to get accurate angle data. The wall of the front courtyard of Wang’s ancestral hall is not rectangular, but an irregular polygon. Therefore, to accurately measure the angle, the manual method has a great error, which is easy to cause the difficulty of alignment between the walls in the later drawing. 3D scanning can be directly linked in CAD, which eliminates the difficulty of measuring angle and is very convenient.

Although 3D laser scanning technology can greatly reduce the workload of surveying and mapping ancient buildings, there are still many problems to be solved, and its disadvantages are mainly as follows:

- There is still room for optimization for the restoration of building details. At present, the accuracy of 3D scanning can meet the requirements of large components drawing. This problem also needs to rely on traditional mapping methods to solve. And this method is safe enough to carry out. Climbing is needed only when the details need to photographed, but one does not need to climb when measuring the elevation and profile data.

- The roof beam column structure of the building cannot be measured through the ceiling. The three-dimensional laser emits visible light and has no penetrability, so the occluded part cannot be scanned and the interior of the staggered component cannot be displayed. The three-dimensional laser
instrument receives the reflection pulse of laser, and the data of specular reflection and material beyond the critical incidence angle cannot be collected [10]. In the actual surveying and mapping, the beam column structure above the floor can only be observed with the help of ladder climbing, which may cause damage to the floor of ancient buildings, and the surveyors also have certain safety risks.

- The color information of the object cannot be obtained. 3D laser scanner is mainly used to obtain the 3D spatial information of the size, shape and location of cultural relics, but it cannot acquire its color pattern and texture information. In order to obtain the color and texture, the camera is used, but the information is lack of integrity and clarity [11].
- The accuracy is affected by natural conditions such as temperature. According to the general equation of laser transmission distance in the atmosphere, the laser echo signal power is related to the atmospheric transmittance from laser source to target, the transmission attenuation coefficient of laser beam in the atmosphere, the reflectivity of target and other variables [12]. Traditional surveying and mapping can be carried out except for extremely bad weather.
- Point cloud data stitching of multi measurement base points is easy to cause point cloud coincidence. It is difficult to fit the point cloud completely in the process of splicing because of the angle deviation of multiple measurements. In this operation, there are multiple roofs and multi-layer beam sections, and even the thickness of point cloud varies due to the characteristics that laser can penetrate some materials.

5. Conclusion
At present, the application of 3D laser scanning technology in Jiangxi cultural relics is still in infancy. There are 11 colleges and universities in Jiangxi Province to open architecture, which is enough to form a surveying and mapping team. From the perspective of cultural relics and buildings protection, Jiangxi needs a lasting, efficient and professional team to map cultural relics and buildings. In view of the above problems, the author believes that the discipline advantage colleges and universities should strengthen cooperation with local colleges and universities, in line with the principle of mutual benefit, while improving the level of surveying and mapping, and promoting the protection of local cultural relics and buildings. Secondly, it is suggested that the Department of Cultural Relics should set up special funds to support the renewal of surveying and mapping tools in colleges and universities. Finally, the Digital Library of Cultural Relics should be established to avoid the dilemma that the ancient buildings are damaged by natural disasters and man-made disasters and cannot be repaired.

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