RESEARCH ON ANALYZING LAND DISPUTESOF HISTORIC BUILDINGS USING 3D TECHNOLOGY

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ABSTRACT: The "Enforcement Rules of the Cultural Heritage Preservation Act" was promulgated by Taiwan in 1984, which require the dimensional relationship between historic sites and lands should be clearly defined in order to effectively manage and maintain them. However, some historic sites situated on private lands that lead to the issues of land disputes. So, these problems are resolved by determining the disputed area with surveying maps overlay the cadastral maps. While, the method is not entirely reliable for non-professional civils, since the results are presented in two-dimensional format. The research takes Huang's You Tang in Kinmen county, Taiwan for example, applying high-precision three-dimensional laser scanning technology to produce 3D digital model for the physical structure of the historic site, and overlay the three-dimensional model and the cadastral map base on the same coordinate system. The research provides a more accurate calculation for the disputed area and offers a three-dimensional visualization digital scene of the area, making it easier for civils to understand the outcome of the dispute. The results of the research show that three-dimensional technology could facilitates the communication and resolution between land disputes, while also expanding and accelerating the management and maintenance of historic sites.

1. INTRODUCTION

Architectural heritage has a great influence on the development of a region and the local culture, and connects different regions with the past history. However, when ethnic emotions and culture create identity, the local customs and development of ethnic activities are livelier and people take active part in various economic and social development, and also yearn for a region with a mellow culture. Therefore, it is an urgent need to maintain and preserve values of historic sites. However, with the passage of time, people have safety concerns about old buildings. For urban renewal, it is imperative to perform monitoring and renovation. In the early stage, historic sites and private land might be controversial due to backward surveying technology and equipment, their location in graphical areas and other factors, and implementation was difficult for some areas with ambiguous future maintenance and land planning and design. Therefore, it is important to clarify the spatial relationship between land objects and cadastres.

According to the Enforcement Rules of the Cultural Heritage Preservation Act promulgated by Taiwan, for recognized historic sites, Article 34 "Construction works or other developments shall not destroy the integrity of historic sites, historical structures, historical structures or traditional gathering habitations, nor shall they obscure their appearance or obstruct their access to view." must be followed. When using large-scale civil engineering and equipment to exploit the land, the vibration conduction generated by the construction may cause irreversible damages to the historic buildings whose structures have been corroded and damaged. Therefore, a clear understanding of the land tenure scope can help better plan the motion lines. The conflict between the current status and the cadastre is also very important information for urban planning and design. Cadastral survey is an important method to solve and clarify the above problems. However, the public has less professional ability to judge the mapping results of cadastral and current status for 2D objects. Therefore, if the active rotating 3D point cloud model can provide people with an understanding of the results from different angles, they would trust the mapping results. The operation advantage of Terrestrial Laser Scanner is that some field operation time can be saved as office operation can be adopted for processing. The data obtained at a lower cost is more abundant and accidental errors, such as centering error, leveling error, and observation error, can be greatly reduced. Therefore, this study uses Terrestrial Laser Scanner to construct the 3D digital scene of the research subject, and uses Electronic Total Station to measure the 2D current status map of the same research subject. The obtained information provides 3D visual overlapping analysis under the same coordinate basis, which can help negotiate with the public on land disputes. Additionally, the 3D digital data patterns, shapes and the real dimensions can help draw and measure the parts that are difficult to be drawn and measured with traditional mapping. Hence, it is an important reference for the future restoration of historical structures and the application of digital added value. The above two devices are described in detail below.

1.1 Literature Review

In recent years, the application of 3D cadastral mapping in land management and urban planning has emerged as a global trend in land policy. The primary tools for 3D mapping often involve various types of 3D Laser Scanners, such as handheld 3D laser scanners. These scanners enable the acquisition of precise location coordinates for land boundaries, complying with cadastral standards. They also provide 3D visualization as auxiliary tools for interpretation, leading to the development of more optimized operational methods [1]. Ground-based and aerial 3D laser scanners are employed to construct 3D urban models, integrating cadastral data to establish land management databases, thereby providing the foundation for subsequent development and taxation regulations [2]. The type of planning is particularly urgent for rapidly growing developing countries facing challenges associated with irregular and unplanned population and housing growth. As a result, the concept of 3D cadastral management has evolved into 4D cadastral management over time to address the challenges posed by irregular population and housing growth [3][4]. The advantages of 3D cadastral management become apparent in such scenarios. In addition to the application of 3D point cloud models for land use management [5], post-processing these models into Building Information Models (BIM) and integrating them with cadastral information in architectural and construction planning enhance construction reliability [6].

Similarly, 3D cadastral management plays an efficiency-enhancing role in reconstruction projects and the cadastral identification of underground structures. For instance, integrating 3D point cloud models of existing conditions with cadastral information enables accurate and rapid subsequent design and construction planning [7][8]. To obtain accurate cadastral information for underground structures, 3D point cloud models need to be overlaid with cadastral maps [9][10]. Therefore, the concept of 3D cadastral mapping, when applied in land management or various other fields, not only meets the requirements of cadastral standards but also provides essential 3D visualization as an auxiliary tool for interpretation. Whether through the generation of 3D cadastral maps or the projection of 3D as-built point cloud models onto 2D as-built plans, these methods offer accurate and efficient assistance in analysis, surpassing traditional methods in accuracy [11][12]. This research is conducted based on the concepts and technical content provided in the literature, serving as a crucial reference for the study and analysis of disputed land identification in historical architecture in Kinmen.

2. DATA ACQUISITION

2.1 Terrestrial Laser Scanner (TLS)

The TLS device used in this study is RIEGL VZ-400, equipped with NIKON D300S camera (as shown Table 1). This LiDAR is Plused Ranging LiDAR, and its maximum scanning distance is 600m. This device can quickly save the current status completely, and the scanning accuracy and precision reach $\pm 5\ mm$ and $\pm 3\ mm$, respectively. The single station scanning time is about 3~5min, and field operators do not need to have cadastral related professional ability. Compared with traditional current measurement, it can reduce the cost of observation error, field operation time and labor. The laser center emits near-infrared light, which is reflected back to the instrument when it touches an obstacle. The distance between the center of the instrument and the obstacle can be calculated by the speed and travel time of the light (see Figure 1), and the point position information related to the location can be obtained. The point data is gathered in a cloud-like shape, so it is called point cloud. However, as laser light cannot pass through the object, the environment cannot be recorded from different angles. Therefore, it is necessary to fill the gaps by constantly moving the instrument. Several stations are matched according to the conjugate points of the environment, and then a complete point cloud model is formed.

Table 1. RIEGL VZ-400 Instrument Specification

- Long range model
  - Scanning distance: $1.5\ m \sim 600\ m$
  - Scanning speed: $42{,}000\ {}^{points}/_{sec}$
- High-speed mode
  - Scanning distance: $1.5\ m \sim 350\ m$
  - Scanning speed: $122{,}000\ {}^{points}/_{sec}$
- Scanning angle: Horizontal 360°, vertical 100°

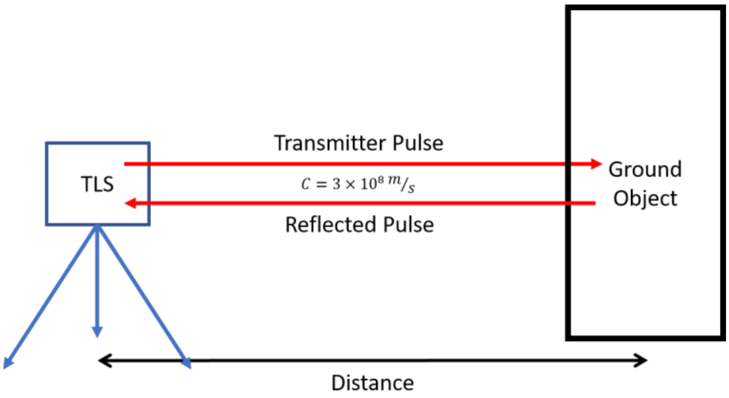


Figure 1. Diagram of Plused Ranging LiDAR

TLS LiDAR is mainly divided into Plused Ranging LiDAR and Continuous Wave LiDAR. The LiDAR used in this study is Plused Ranging LiDAR. The calculation formula of laser light ranging is as follows (Equation 1). R is the distance traveled by Plused Ranging LiDAR, C is the speed of light ($3 \times 10^8\ {}^{m}/_{s}$), and T is the time required for the travel distance of the Plused Ranging LiDAR. As a tool for 3D spatial scene reconstruction, this device and related post-production technology are also mature and effective spatial information technologies.

$$\boldsymbol{R} = \frac{1}{2}ct \tag{1}$$

2.2 Electronic Total Station

In traditional surveying and mapping, Electronic Total Station is used as a tool for controlling surveying, 2D current status map surveying and cadastral surveying. The model of Electronic Total Station used in the study is Trimble 5603 DR200+ (see Table 2), which is a reading instrument with angle measurement of 1" and with a standard deviation of $\pm 3''$. When the distance between the measuring station and the prism is 5~200 m, the ranging accuracy is$\pm(\ 3\ mm + 3\ ppm)$. This complies with Articles 57 and 58 of the Cadastral Surveying Implementation Rules promulgated by Taiwan: "For the horizontal angle of the mapping control point, a theodolite with an accuracy of six seconds (inclusive) should be used", and "for the distance measurement, an electronic distance measuring instrument with an accuracy of $\pm(5\ mm + 5\ ppm)$ (inclusive) shall be used". This device and related technologies are used to obtain the 2D current status map information of the research subject, which can be used as the source information for comparison and analysis with the 3D point cloud digital model.

Table 2. Trimble 5603 DR200+

	● Angle measurement: 1" ● Angle standard deviation: 3" ● Ranging accuracy with prism ■ $5\sim 200\text{m}: \pm(\ 3\ mm + 3\ ppm)$ ■ $> 200m: \pm(5\ mm + 3\ ppm)$

3. EVALUATION OF ORTHOGRAPHIC PROJECTION EFFECTIVENESS

To explore the difference between 3D point cloud model and 2D current status map obtained by traditional surveying and mapping with the same scene and subject, overlapping analysis can be performed on the two to reveal the results. The 3D point cloud model can obtain the 2D map information by orthographic projection. The 2D map information is overlaid with the 2D current status map measured by Electronic Total Station to obtain the difference analysis of space and properties between the two. The TLS device provides the corresponding point cloud data processing software. Orthographic projection is also one of the functions provided by it. This function is also commonly used in user data processing. However, the accuracy of 2D images after orthographic projection has not been verified. Therefore, this study aims to implement outdoor experiments. Under the premise of fully mastering the leveling of the scanning device, this study analyzed the overlapping results of 2D map data after orthographic projection of 3D point cloud model and 2D map data of traditional surveying and mapping. Their differences and applicability were evaluated for reference in future practical operation. Therefore, in this study, before TLS was used to discuss land disputes in cadastral maps, the reliability assessment of the orthographic projection function of commercial software were performed. The experimental flow of orthographic projection evaluation is shown in Figure 2:

- Analyze the deviation of building line expansion obtained from the orthographic projection of the point cloud data of a single scanning station and the complete point cloud model.
- Analyze the deviation of building line expansion obtained from the orthographic projection of the point cloud data of a single scanning station and the converted TaiWan Datum 1997(TWD97) complete point cloud model.
- Analyze the deviation of building line expansion obtained from overlapping of the complete point cloud model (TWD97) after orthographic projection and the 2D current status map measured by Electronic Total Station (TWD97).

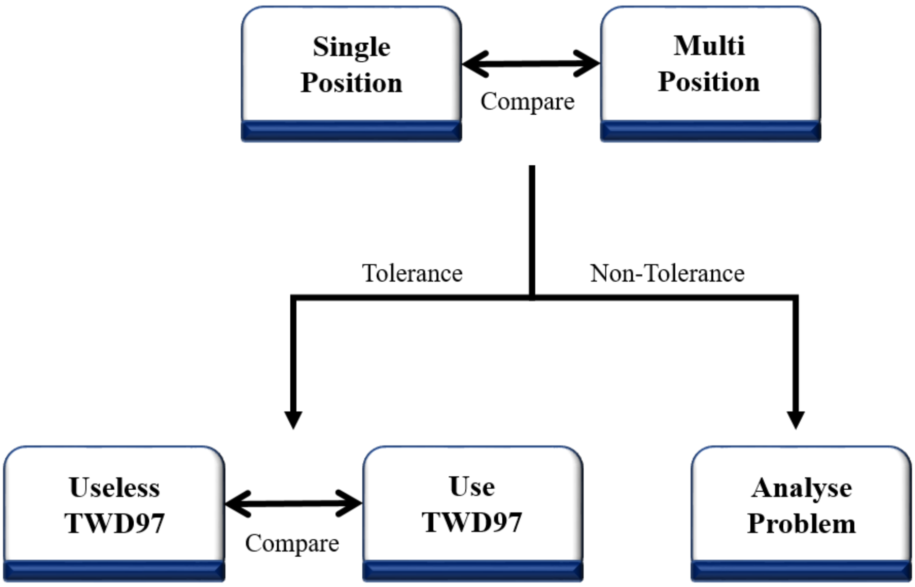


Figure 2. Flow Diagram of Experiment of Evaluation of Orthographic Projection Effectiveness

In this study, Yeoh Tiong Lay Garden of National Quemoy University was taken as the experimental subject, and the drip line of the building was taken as the target of deviation evaluation. RIEGL VZ-400 (Riscan Pro post-production software) and Trimble 5603 DR200+ were used to obtain the complete point cloud data of the building and the mapping data of the building drip line. The connection result of the point cloud model is shown in Figure 3, and the standard deviation is $\pm 0.0035\ m$ (Figure 4). According to the orthographic results of a single station and the orthographic results of a complete point cloud model, after the peripheral lines were drawn and overlapped, the deviations of five positions were measured (see Table 3). The maximum deviation value is $0.0054\ m$, which is lower than the error specified by the Cadastral Surveying Implementation Rules.

Figure 3. Point Cloud Model after Connection with Yeoh Tiong Lay Garden

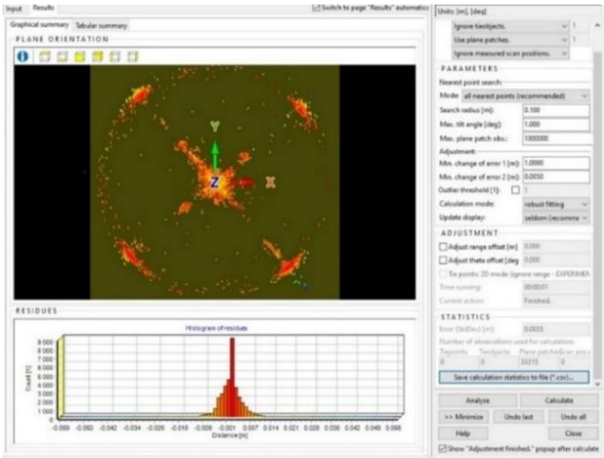
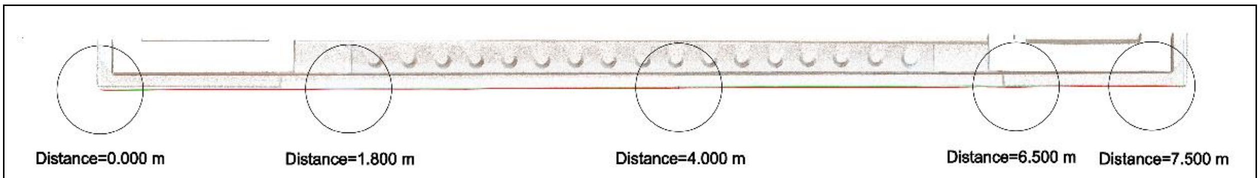


Figure 4. Connection Adjustment Results of the Point Cloud Model

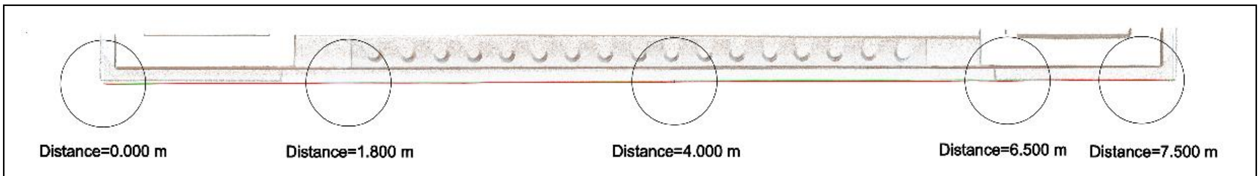
Table 3. Comparison Table of Line Expansion Deviation between Single Station and Multiple Stations



Location (m)	0.000	1.800	4.000	6.500	7.500
Difference value (m)	0.0020	0.0005	0.0054	0.0031	0.0045

The mapping control point of existing TWD97 coordinate values was used as the control point. After it was confirmed to be correct via testing, its coordinates were guided to the experimental area as closed traverse for control use. Three-point distribution of control points after testing is shown in Figure 3 (pink points). The calculated traverse closure ratio is $\frac{1}{8096}$, and the standard deviation of complete point cloud model converted to TWD97 is $\pm 0.0011\ m$. After the point cloud data of the single station was converted into TWD97 complete point cloud model, the maximum line expansion deviation of the building is $0.0084\ m$ (Table 4), which is also lower than the error specified by the Cadastral Surveying Implementation Rules.

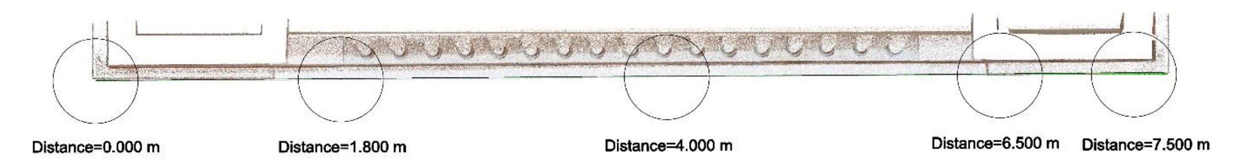
Table 4. Comparison Table of Line Expansion Deviation between Single Station Point Cloud Data and TWD97 Complete Point Cloud Model



Location (m)	0.000	1.800	4.000	6.500	7.500
Difference value (m)	0.0000	0.0005	0.0084	0.0065	0.0047

Subsequently, the control points obtained at three points in the experimental area were used to measure the drip line with the Electronic Total Station, and the 2D current status map drawn by the traditional surveying method was obtained. Moreover, the overlay analysis was performed with the orthographic map with the complete point cloud model with TWD97 coordinates, and the resulting deviation of the building expansion line was obtained. The maximum deviation of its line expansion is $0.0069\ m$ (Table 5), which is also lower than the error specified by the Cadastral Surveying Implementation Rules.

Table 5. Comparison Table of Line Expansion Deviation between Traditional 2D Map and Digital Model



Location (m)	0.000	1.800	4.000	6.500	7.500
Difference value (m)	0.0035	0.0046	0.0024	0.0069	0.0056

After integrating the analysis data in Tables 3~5, 2D orthophoto is obtained by orthographic processing of 3D point cloud data converted into TWD97 coordinate system. In the judgment of the disputed land related to architectural monuments, in addition to complying with the accuracy requirements of the Cadastral Surveying Implementation Rules, the visual effect of 3D visualization needs to be met, which can accelerate the correctness and ductility of the judgment.

4. RESEARCH METHOD

4.1 Research Site

Based on the orthographic function evaluation experiment of the software produced by the point cloud, the results of cadastral survey correspond to the standard error of Cadastral Surveying Implementation Rules when cadastral survey is conducted because architectural historic sites and other objects cause land dispute. Accordingly, this study was conducted at Huang's Ancestral Hall in Jincheng Township, Kinmen County (Figure 5). Huang's Ancestral Hall was built by Bai-wan Huang (Chun Huang) during the Jiaqing period of the Qing Dynasty, and is called ancestral separate industry because it was built in the lunar year Yiyou. It is the only building with a pool before the house in Kinmen County. It is in a half-moon shape. A granite stone bridge divides the pool in two. The round part with a larger area is known as the sun pool, and the other part with a smaller area is known as the moon pool, which are collectively known as the Sun and Moon Pool. The ancestral hall was declared a second-class historic site on November 11, 1988, and upgraded to a national historic site in 2000. In this study, the Electronic Total Station and the traverse measurement free station method were used to set up the control points with TWD97 coordinate system as the coordinate source of the 3D point cloud model and the traditional 2D current status map, and the 3D point cloud model was orthographically projected into 2D plan. Subsequently, the feasibility of 3D point cloud model assisting the traditional current status map in the judgment of disputed land and judgment and interpretation of 3D vision optimization dispute was evaluated.

Figure 5. Location of Huang's Ancestral Hall, in Jincheng Township (Kinmen County)

4.2 Control Surveying

For example, the control point of Huang's Ancestral Hall with TWD97 coordinate system was arranged by the method of free measuring station in this study. The calculated angle assignment value was -23.89” and the angle closure ratio was $\frac{1}{13987}$, which was much higher than the accuracy "horizontal angle closure difference $< 20"\sqrt{n}$ (n: number of traverse points), traverse closure ratio $< \frac{1}{5000}$ required by the Cadastral Surveying Implementation Rules. The traverse network diagram is shown in Figure 6, and the coordinate values of traverse control points are shown in Table 5.

Figure 6. Traverse Network Diagram

Table 5. Traverse Control Point Coordinates

ID	N(m)	E(m)	ID	N(m)	E(m)
H94808	2700647.343	178842.445	YT08	2700651.454	178806.161
H04135	2700618.504	178816.155	YT01	2700628.163	178822.804
H94809	2700687.589	178866.018	YT04	2700702.229	178831.867
H94811	2700694.826	178790.634	YT05	2700705.455	178819.621
YT02	2700653.894	178845.580	YT06	2700714.292	178793.741
STM071	2700659.025	178852.147	YT07	2700678.466	178799.861
YT03	2700694.022	178847.145	STM066	2700662.757	178797.347

4.3 Point Cloud Model

There were a total of 8 stations for field scanning and the operation only targeted at land dispute or the outermost line expansion of the building. Therefore, four control points were scanned by TLS. The point cloud coordinate system scanned by TLS stations is the instrument center (0,0,0), so Riscan Pro point cloud processing software launched by RIEGL is used in the internal industry to build point cloud models based on the spatial correlation of the actual environment of each station. The standard deviation of the overall model was $\pm 0.0037\ m$. Then the point cloud model was converted to TWD97 coordinate system, and the standard deviation of coordinate conversion was $\pm 0.0037\ m$. After all point clouds were exported to Las file, they were converted to rcs file in Autodesk Recap and imported into AutoCAD to analyze the land dispute concerning current status with cadastral map overlap. After examination, the difference of control point coordinates of the point cloud model after conversion is shown in Table 7, and the overlap of the point cloud model and cadastral map is shown in Figure 7.

Table 7. Difference of Point Cloud Model Control Point Coordinates after Conversion

ID	∆N(m)	∆E(m)	∆L(m)
YT03	-0.019	-0.035	0.040
YT07	0.007	0.028	0.029
YT08	0.010	0.026	0.028
YT02	0.002	-0.020	0.020

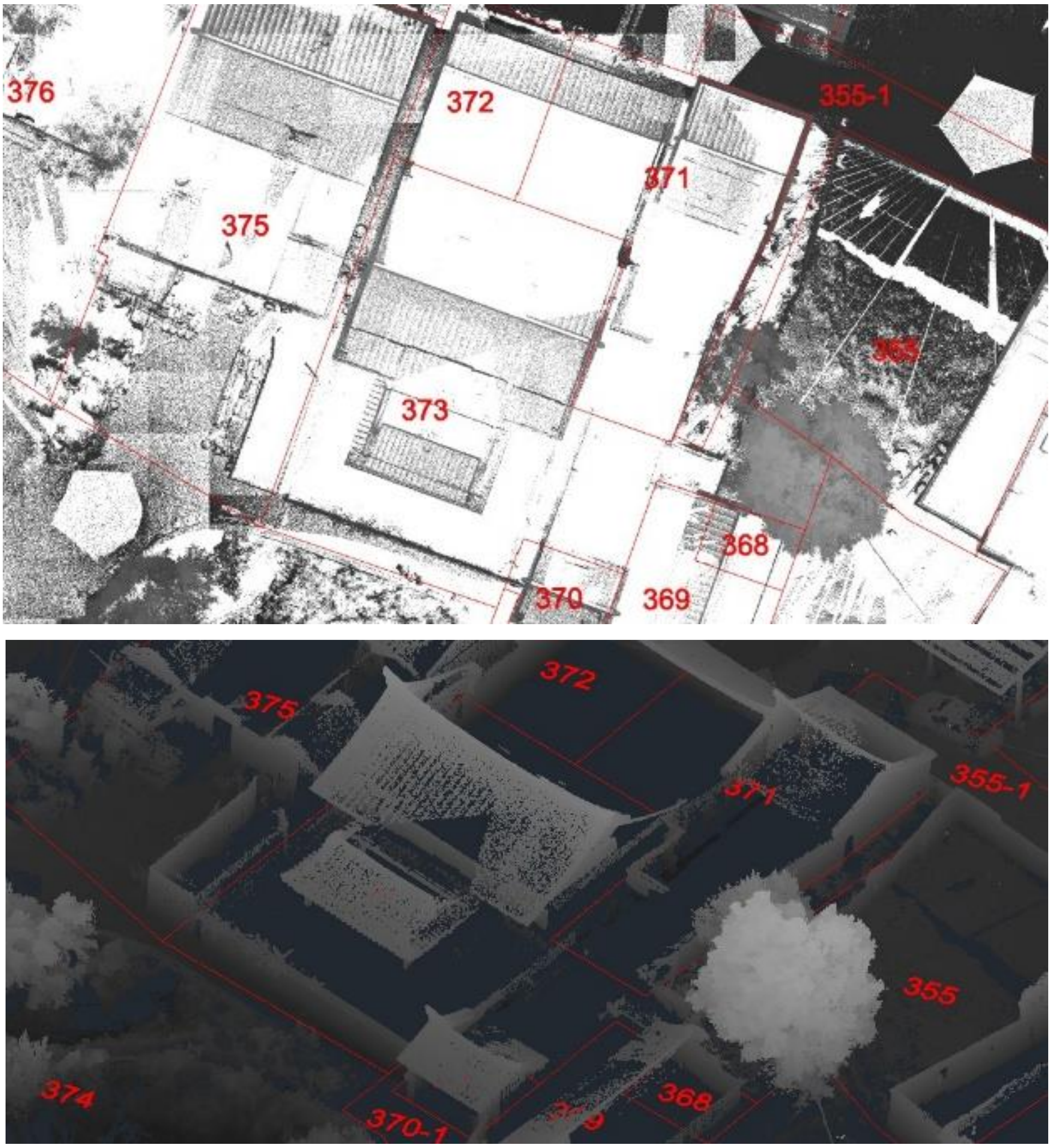


Figure 7. Overlapping of Point Cloud Model and Cadastral Map

5. LADN DISPUTE

Through overlapping analysis of the orthograph of the point cloud model (light blue line) and the cadastral map (red line), it can be clearly judged that the drip line of the national historic site "Qianshuitou Huang's Ancestral Hall" encroaches on other people's land (Figure 8). The deviation was measured using AutoCAD software. The left part of Figure 8 shows that its encroachment range is about 12~14cm, and the right part of Figure 8 shows that its encroachment range is about 12~14cm. In addition, according to the mapping shown in Figure 8, it is difficult to judge the special shapes of traditional buildings in southern Fujian (e.g., phoenix tail, swallow tail, horseback) by using traditional surveying and mapping methods. However, the 3D point cloud model can be used to clearly analyze their component shapes, judge and measure the encroachment and data. It can be seen that the 3D point cloud model can be applied to obtain relevant information in the special modeling department, and to provide the judgment of land disputes in line with the requirements of Cadastral Surveying Implementation Rules. In particular, with the visual effect of 3D visualization, it can help to communicate and explain with the public more quickly.

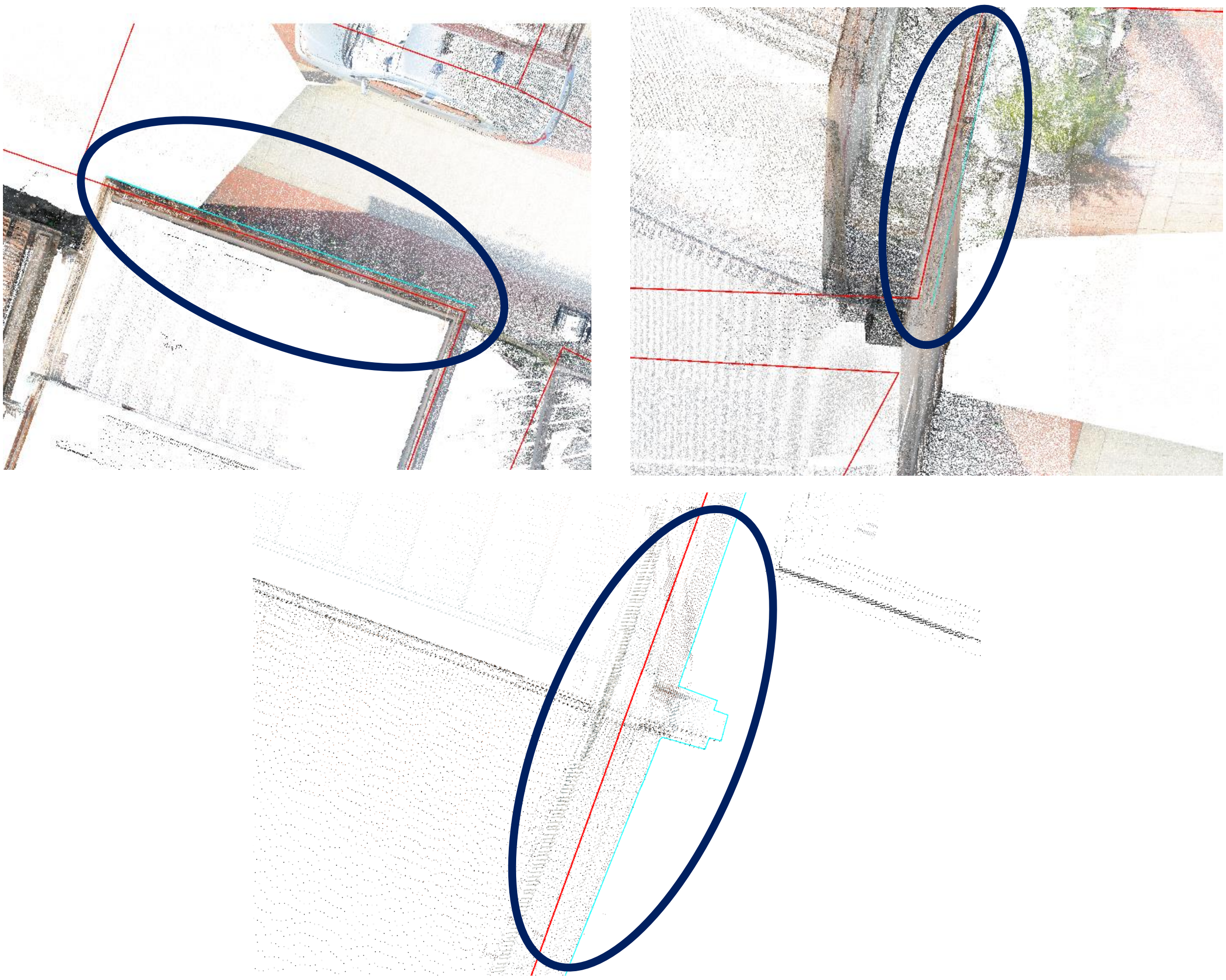


Figure 8. Area of Land Dispute

6. CONCLUSION

Measurement is accompanied by errors. Such errors are roughly divided into accidental errors, systematic errors and mistakes. The limit of instrument precision, the limit of human sensory acuity, and the abnormal distribution curve of atmospheric environment change in the measuring area are all accidental errors. These errors can mostly be eliminated by multiple measurements and numerical corrections to reduce errors. Instruments and natural factors may also lead to errors, which are small and cumulative, and are systematic errors. Mistakes are usually large in the measurement data, and the causes are mostly human negligence factors. There are many kinds of errors in the traditional surveying method of mapping the current status plan. In particular, in the field operation process, the surveyor needs to align the object through the telescope, and human factors lead to accidental errors, the probability of errors is greatly increased and the amount of errors cannot be predicted. However, if the TLS method is adopted for mapping, it does not involve too many human factors. Hence, in theory, the types of errors are reduced, such as centering and leveling errors, observation errors. However, TLS method increases systematic errors, such as scanning and connection errors, and orthographic projection effect of software. It is understood from the above evaluation of orthographic projection effect that the systematic errors are much higher than the accuracy required for cadastral survey. Based on the theory of error type and law of error propagation, it can be seen that the mapping accuracy of 3D laser scanning technology is higher than that of traditional measurement.

The experimental results show that whether the single point observation position is correct cannot be verified for most of the drip lines, columns, swallow tails and phoenix tails that are orthographically projected from buildings in traditional surveying and mapping using Electronic Total Station. For example, whether the laser light is scattered and ranging to the wall, or even if the environment is too complex to be measured, it is often made up by mapping, but the point quantity system obtained by TLS is very large, and the surrounding environment can be preserved more quickly, and the measurement boundary ranging can be measured multiple times in the computer to reduce accidental errors and prevent errors. The use of the point cloud model produced by TLS and mapping of building perimeter extensions has been very effective in discussing land dispute concerning historic sites. In the past, literary examiners were less able to understand the relevance of drawings to their current location. Therefore, it is difficult to formulate a policy for the maintenance and preservation of historic sites. It is now possible to draw cadastral maps, and urban plans more efficiently with the current status. During the coordination and communication with the public on land issues, the survey results are more clearly presented in order to convince them.

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