RESEARCH ARTICLE

Discussion about the Application of GEOSLAM Hand-held 3D Laser Scanner to the Surveying into Rural Real Estate

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Abstract: With the increasing development and application of three-dimensional laser scanning technology, it becomes possible to realize automatic and efficient surveying with a high level of convenience and precision via ground mobile surveying system. The traditional laser scanning equipment cannot meet the work requirement due to its relatively low working efficiency given the high accuracy requirements, large density houses, complex situation in the courtyard and large amount of data involved in the surveying of House Ownership and Land-Using Right Integration(or Real Estate). Besides, it has to rely on GNSS and inertial navigation system, which the novel three-dimensional laser scanning method does not need. The fixed laser scanning, though it can be used in both indoor and outdoor environment, fails to meet the working requirement as well with its relatively low data acquisition efficiency as complex places require a large number of station changes and point cloud matching. While Mobile real-time positioning and map construction technology, with the features of high precision, easy portability, fast data processing and intuitive graphics acquisition, proves that it can be popularized in the integrated surveying project of rural real estate as a new method because it not only improves work efficiency, but also ensures mapping accuracy.

Keywords: SLAM; House ownership and land-using right integration; Three-dimensional laser scanning; Mobile surveying system

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1. Introduction

It is required that the confirmation and registration of House Ownership and Land-Using Right Integration should be basically completed by the end of 2020, according to *the Outline of the 13th Five Year Plan for National Economic and Social Development, Several Opinions of the CPC Central Committee and the State Council on Giving Priority to the Development of Agriculture and Rural Areas and Doing a Good Job in the Work of "Agriculture, Rural Areas and Farmers", Notice of the Ministry of Land and Resources on Issues Related to Further Accelerating the Right Confirmation, Registration and Certification of Homestead and Collective Construction Land,* and *Notice of the Natural Resources Authority on Further Completing the Right Confirmation and Registration of Rural Real Estate.* Considering the wide scope and tight time of this task, the means of field operation are a matter of concern [1,2].

At present, the two most commonly used methods of field surveying are graphical method and analytical method (whole field measurement method). Graphic method can greatly reduce field work, but the mapping accuracy is low, and some field work is still needed; Analytical method ensures high precision and accuracy, but the tedious work and the tight schedule cannot be ignored. Therefore, the two methods above have their respective strength and weakness. While the new surveying technology adopted in this paper, namely mobile Simultaneous Location And Mapping (SLAM) technique, can meet the accuracy need in the House and Land Integrated Surveying project and improve the operation efficiency to a high extent by greatly reducing the labour input and many complicated steps during the interior processing.

2. Main Surveying Techniques in Modern Times

Automation, visualization and digitization are attached much attention in today's surveying techniques, hence the introduction of novel technique and equipment becomes crucial. At present commonly used surveying methods are traditional manual measurement (analytical method), UAV tilt photogrammetry, surveying via ground-based 3D laser scanner, airborne laser radar and hand-held 3D laser scanner, etc.

2.1 Traditional Manual Measurement (Analytical Method)

Traditional manual measurement (analytical method) refers to the whole field measurement technique. Although the data collected by this method possesses high accuracy, the human error in the process of data collection compared with the automatic surveying still cannot be ignored. Besides, the labor cost is becoming increasingly high, and the labor efficiency varies from person to person due to the different work experience.

2.2 UAV Tilt Photogrammetry Technique

Barely affected by land forms, UAV tilt photogrammetry can be used in large scope operation with a high data collection efficiency.

Moreover, it can better reflect the real landform and features as the collected data have real texture and other information. However,it takes a long time to process indoor data because of a large volume of data. Besides, UAV is seriously restricted by weather, which leads to an uncertain project schedule. And this technique cannot be applied to indoor operation.

2.3 Ground-based 3D Laser Scanning Technique

The ground-based 3D laser scanning, achieving a high precision within a single station by using high-pixel camera that collects color point clouds, is mainly applied in fields including ancient architectures. However,the frequent transfer of operating stations plus heavy equipment make the efficiency relatively low.

2.4 Airborne Laser Radar Technology

Airborne laser radar can be applied to the surveying of earthwork, vegetation coverage, and land forms and features (such as houses) in a large area, as well as power grid patrolling and crop disease monitoring. Thanks to its high-precision and wide-area point cloud data, it has become an indispensable technical means in the field of surveying and mapping. However, airborne laser radar is also constrained by the inherent conditions of UAV operation, which needs to take flight safety into consideration. And it fails to satisfy the point cloud density in complex terrain, neither can it collect indoor information. Moreover, it is expensive, which discourages many users, making the technology unable to be widely used [3].

2.5 SLAM Technique

SLAM Technique ensures high precision assisted by handheld, backpacked, or vehicle mounted 3D laser scanning. It proves high efficiency in the data acquisition on ground. Moreover, less manual intervention needs to be involved for the indoor and outdoor point clouds can be automatically spliced. SLAM technique plays an irreplaceable role in underground surveying including 3D modeling of mine and roadway [4].

Technical means varies according to different application scenarios and accuracy requirements. A type of equipment, or many different types of it, should be adopted based on realities. In such way the operation efficiency could be improved to the maximum extent possible.

3. SLAM Technique

SLAM refers to a method by which a scanner moves in unknown environment, locates itself and builds an incremental map based on the position during the moving, thus to realize autonomous localization and navigation.

Generally, if the laser scanner is installed in the mobile measurement system, there must be a high-precise positioning system (POS system) to match it, so that the laser points obtained by the laser scanner can acquire the corresponding data of position and pose, and then synthesize the three-dimensional laser point cloud. Then how to reverse calculate the high-dynamic and nonlinear position and pose of laser point clouds? By studying the algorithm of laser point cloud processing, we can find clues from these disordered point clouds, obtain the more stable eigenvalues and eigenvectors, continuously track these eigenvalues and eigenvectors, and then reversely calculate the position and pose of scanner with high precision. This method for working out scanners' position and pose with high-precise in a dynamic and reverse way overturns the traditional surveying and mapping method by providing novel technique [5].

3.1 Working Principle

Thanks to its unique technique, SLAM can be used for applications in all kinds of fields, particularly indoor, underground and inaccessible spaces. It can provide high-precise 3D map without GNSS. Broadly speaking, SLAM composes three processes, namely sensing, localization and mapping.

Sensing: It can acquire the environmental information around it through the sensor;

Localization: Estimate its own position and pose through the current and historical data obtained by the sensor;

Mapping: Draw the appearance of the environment around it according to its own position and pose and the information obtained by the sensor [6].

Its working principle is shown in Figure 1.

3.2 Technical Features

SLAM does not rely on GNSS signal—except when the accurate data of the absolute control point is needed—and shows strong adaptability to the working environment, so the SLAM mobile surveying system plays a role in many surveying and mapping fields, which is specifically shown as follows:

When working outdoors, it is able to acquire point cloud data of high precision at a rapid speed.

Point cloud could be matched within a short time due to its fast processing; no manual intervention is needed because of its high automation.

With easy and convenient operation as well as continuous working ability, integrated scanning for indoor and outdoor environment can be realized.

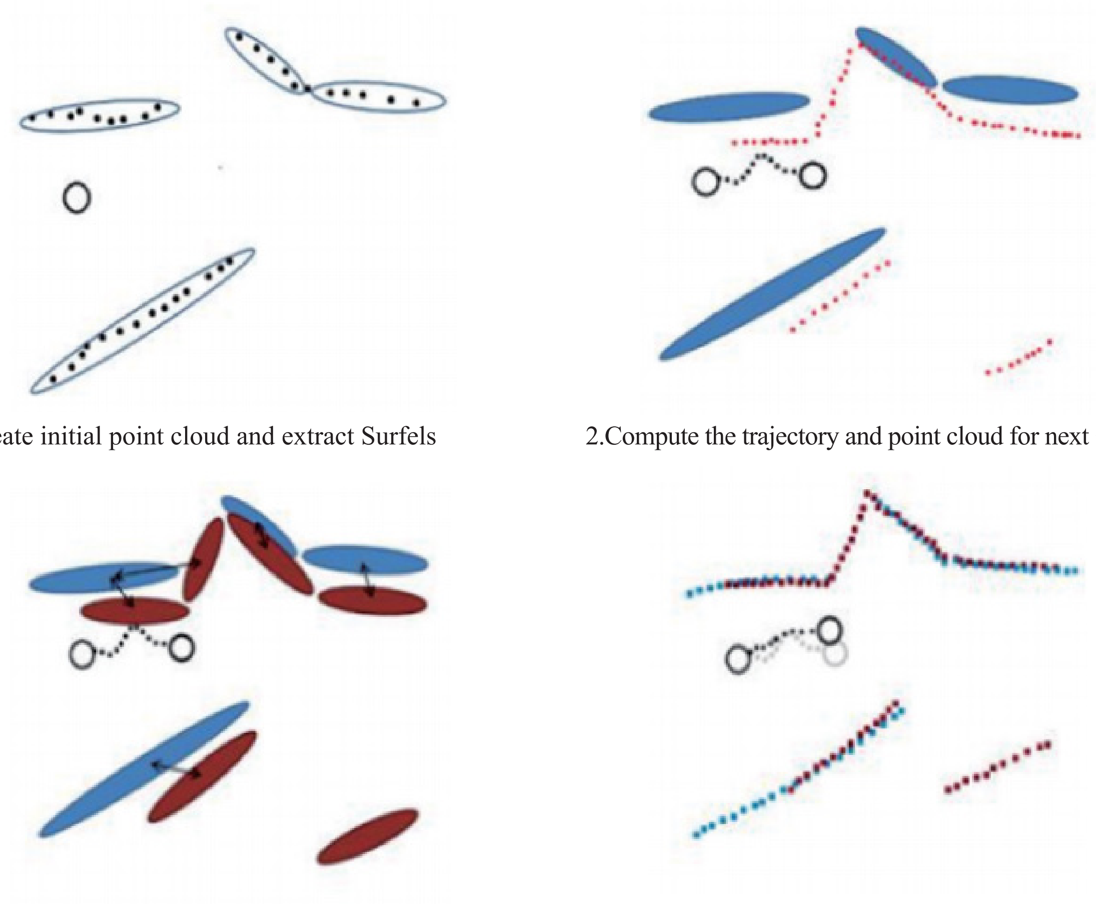
The SLAM handheld 3D laser scanner ensures long-time working in any environment with low failure rate. For key areas which has high accuracy requirements, it can be used in conjunction with fixed station 3D laser scanner to ensure both accuracy and efficiency.

4. Application of GEOSLAM to Surveying of Rural Houses and Lands Integration

4.1 Operation Procedures

The investigation into the the rural house ownership and land-using right integration aims to establish the database of real estate(or house ownership and land-using right integration)via information and technology through comprehensively checking out buildings and structures such as houses on homestead and collective construction land [7].

The procedures of integrated surveying using GEO-SLAM are shown in Figure 2.



1.Create initial point cloud and extract Surfels

2.Compute the trajectory and point cloud for next scanning

3.Extract and match Surfels through the two scanning

4.Optimize the trajectory and recreate point cloud

Figure 1. Working Principle

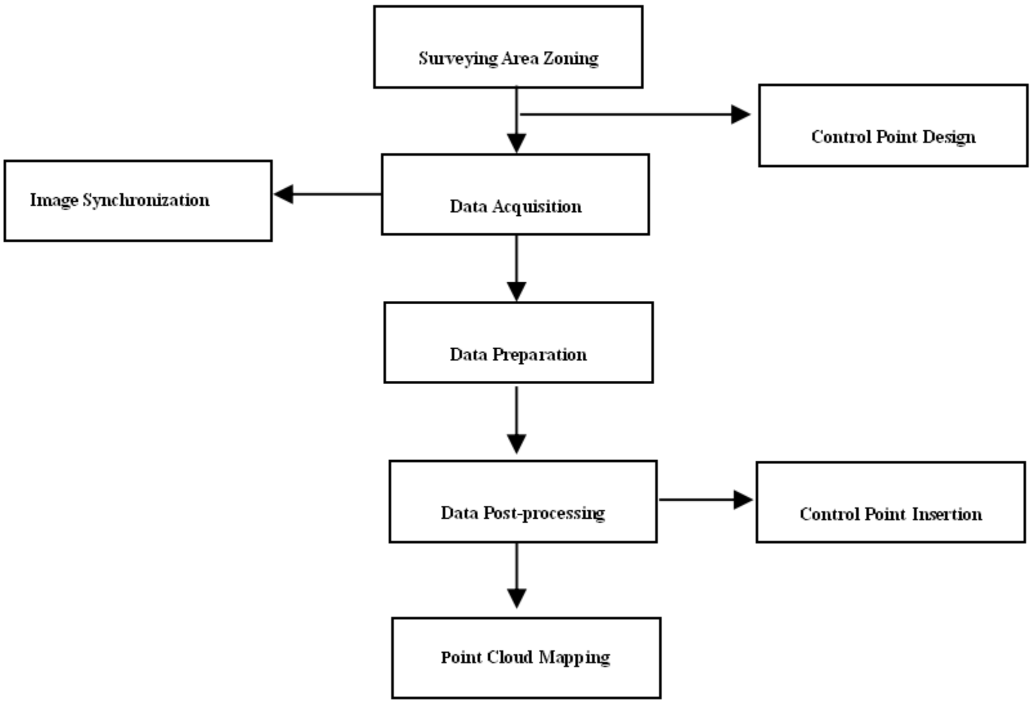


Figure 2. GEOSLAM Operation Flowchart

4.2 Data Acquisition

Equipment used for field data acquisition include GEOSLAM equipment, GNSS, reflective markers of image control points, etc. Since SLAM does not have an absolute localization system, when it is necessary to obtain the absolute position coordinates, it needs GNSS and reflective marker's help to obtain the control data before correcting the coordinates of the scanned data [8].

(1) Arrange 3-4 image control points in a survey section using reflective labels and they should be evenly distributed on noticeable features;

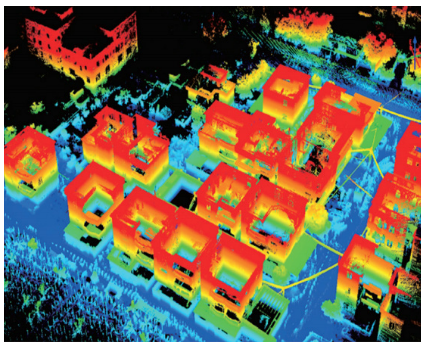
(2) Collect the coordinates of image control points using GNSS RTK;

Before scanning is started, the trajectory should be designed in advance, shaped as multiple closed loops. Using loop closure is to make point cloud algorithm more matching and results more precise. The whole measuring time shall be limited within 25min, mainly considering the observation fatigue and the rate of office data analysis [9].

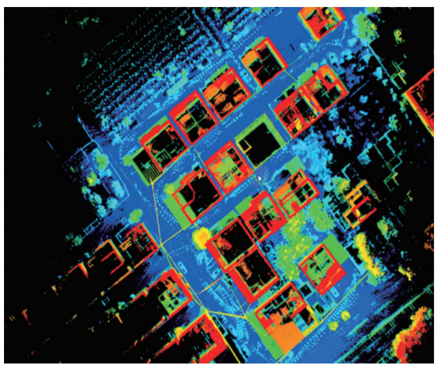
4.3 Office Data Processing

4.3.1 Data Computing Stage

Import the original data through the data preprocessing software GEOSLAM Hub to compute. Generally, computing time is about 1 to 3 times as long as scanning time. The overall 3D and 2D images of point cloud data could be checked in GEOSLAM hub. It could also be displayed in RGB true colors—different materials in different colors—as shown in Figure 3, which helps compare the accuracy of the final results more intuitively [10].



a. 3D Artist's Impression



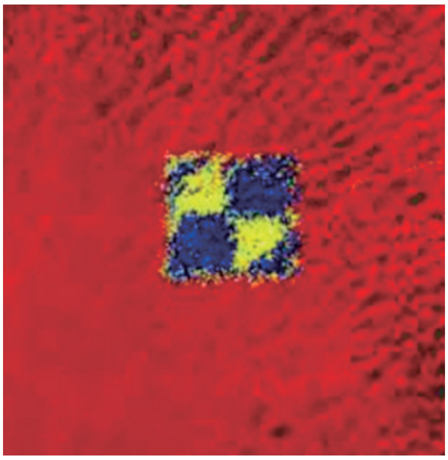
b. 2D Artist's Impression

Figure 3. Data Preprocessing Artist's Impression

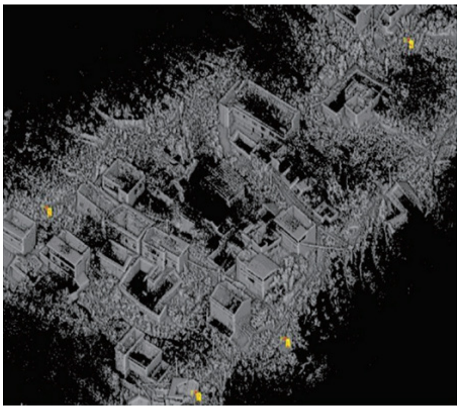
4.3.2 Point Cloud Coordinate Transformation

Since there is no GNSS record for the point cloud data, it needs to coordinate transformation after being processed. There are two ways to transform the coordinates: the first one is to match the overall point clouds within the surveying sections, then transform the coordinates using the image control points; the second one is to transform the coordinates firstly without point clouds matching, superimpose the data afterwards.

Firstly, find the image control points in point cloud, highlight them in point clouds, as shown in Figure 4.



a. Mark of Image Control Point



b. Distribution of Image Control Point

Figure 4. Distribution of Image Control Point

As can be seen from Figure 4, the image control points are evenly distributed, and they can also be collected in a small range of closure. Compute parameter by using the coordinate data of GNSS RTK and point cloud of image control points according to the requirement of coordinate transformation. Check data through field work after transformation.

The mean square error of boundary point coordinates obtained by laser point cloud shall meet the accuracy requirements of the Integrated Surveying, as shown in Table 1:

Table 1. Accuracy Requirements for Parcel Boundary Points

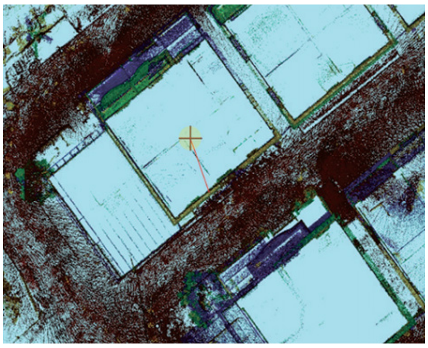
Level	Error between boundary point and adjacent control point, error between adjacent boundary points (cm)	
	Mean Square Error	Permitted Error
1	±5.0	±10.0
2	±7.5	±15.0
3	±10.0	±20.0

Note 1: The accuracy of evident boundary points shall not be lower than level 1, and hidden points level 2

Note 2: Land using right boundary points can be level 1, 2 and 3

4.3.3 Point Cloud Post-processing Stage

For the point cloud data (in RCS format) that meets the accuracy requirements after coordinate transformation, open it through a third-party software (such as Realworks or other similar one), after data thinning and simplification, cut the redundant parts, and output RCP files. This format is for the convenience of cartographers' creating graphics through cartographic software CAD or CASS. The data comparison before and after processing is shown in Figure 5.



a. Before Date Thinning

b. After Date Thinning

Figure 5. Comparison Before and After Data Thinning

4.3.4 Mapping

Load point cloud data using AutodeskCAD and CASS software to map. Different panel data shall be cut according to the corresponding floors of the same building. The specific drawing process is shown in Figure 6.

4.4 Analysis of the Experimental Results

This paper compares SLAM technique with traditional surveying method, taking a village in Lvliang county, Lishi district--with approximately 300 households there--as experimental area.

4.4.1 Precision Comparison between the Two Methods

The experiment randomly chose 30 boundary site lengths for precision comparison, and the results are as follows:

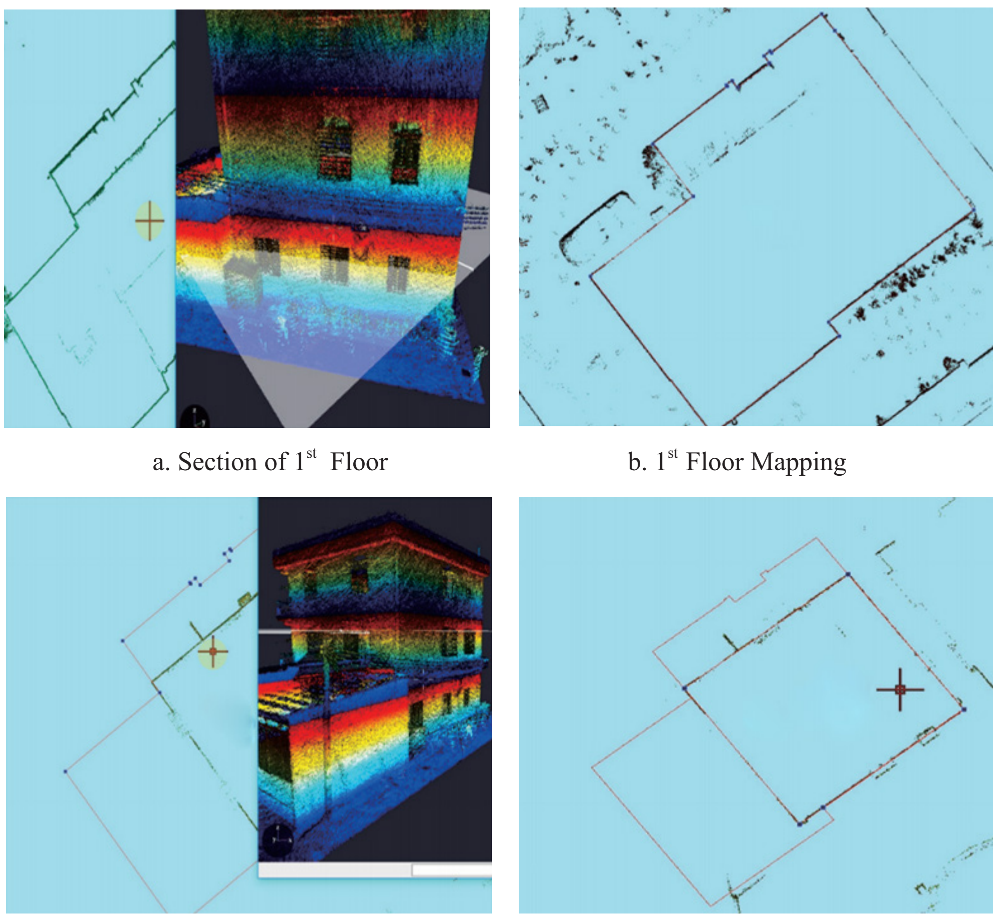
As the comparison result shows, all side lengths are within the limit with the maximum error being 0.09 m, the minimum 0 m, the mean square error ± 0.03 m, which meets the accuracy requirements of rural right integrated surveying.

4.4.2 Efficiency Comparison of the Two Methods

As the comparison result shows, GEOSLAM is about 11 times the efficiency of traditional measurement in field surveying. The office processing efficiency of the two methods is basically the same. Thus we may say that, GEOSLAM significantly improved efficiency--it is 5 times as efficient as the traditional one.

5. Conclusions

In the case concerning SLAM technique mentioned in this paper, GEOSLAM handheld 3D laser scanner was applied to the surveying into Rural House Ownership and Land-using Right integration, which greatly improved the field efficiency and accumulates valuable work experience. Besides it saves time, and reduces the cost of labour and materials. More importantly, accuracy is guaranteed to a great extent.



a. Section of 1st Floor　　b. 1st Floor Mapping

c. Sections of 2nd and 3rd Floors　　d. Mapping of 2nd and 3rd Floors

Figure 6. Point Cloud Mapping

Table 2. Comparison of Measurement Accuracy

No.	Field Measured Side Length/m	Inverse Computation Side Length/m	Error/m	Whether exceed the limit
1	10.51	10.56	–0.05	No
2	10.06	10.07	–0.01	No
3	10.09	10.11	–0.02	No
4	10.12	10.13	–0.01	No
5	10.10	10.08	0.02	No
6	10.51	10.53	–0.02	No
7	10.92	11.01	–0.09	No
8	10.56	10.65	–0.09	No
9	10.62	10.57	0.05	No
10	5.07	5.10	–0.03	No
11	6.61	6.59	0.02	No
12	5.03	5.06	–0.03	No
13	10.01	10.06	–0.05	No
14	5.05	5.05	0.00	No
15	10.04	10.11	–0.07	No
16	9.94	9.94	0.00	No
17	5.07	5.09	–0.02	No
18	10.1	10.14	–0.04	No
19	9.05	9.07	–0.02	No
20	11.02	11.05	–0.03	No
21	8.59	8.56	0.03	No
22	5.30	5.24	0.06	No
23	11.10	11.02	0.08	No
24	11.97	11.99	–0.02	No
25	5.96	5.98	–0.02	No
26	10.04	10.05	–0.01	No
27	10.05	10.09	–0.04	No
28	10.05	10.07	–0.02	No
29	4.97	5.00	–0.03	No
30	10.08	10.09	–0.01	No

Table 3. Comparison of Working Efficiency

Types	Number of Surveyor	Time Required for Traditional Surveying	Time Required for GEOSLAM
Field Surveying	2	11 Days	1Day
Office Processing	1	1 Day	1Day
Field Checking	2	1Day	1Day
Total		25 Surveyor.Day	5 Surveyor.Day

At present, there are many types of 3D laser scanners, and handheld scanner is a good choice for small-scaled integrated surveying in which residential buildings are in high density. Its operation is flexible, and field scanning could be completed by one single person. The operation time is predictable, so the overall plans could also be drawn up in the early stage.

If the SLAM method is combined with UAV tilt photogrammetry technique according to local conditions, it will be applied to more fields. As the cost of labour grows higher and higher in recent years, the advantages of novel techniques and equipment are becoming increasingly conspicuous.

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