Design of 3D Reconstruction Model of Complex Surfaces of Ancient Buildings Based on Big Data

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Abstract. Over time, ancient buildings have remained in the natural environment for a long time, and damage often occurs. Therefore, in order to protect the cultural heritage of these materials, repair work is essential. Under this background, a three-dimensional construction method of complex curved surface of ancient buildings based on big data is proposed to complete the three-dimensional modeling of ancient buildings. The model construction is mainly divided into three steps: the first step uses LiDAR to obtain the LiDAR point cloud data and image data of the complex surface of the ancient building; the second step processes the data, including the processing of LiDAR point cloud data and the processing of image data; The method combines LiDAR point cloud data with image data to automatically generate a three-dimensional model of complex curved surface of ancient buildings. The results show that compared with the other two traditional methods, the accuracy of the method is higher, and the model coordinate points are closer to the real coordinates.

Keywords: Big data · Ancient architecture · Complex surface · Three-dimensional reconstruction model · Lidar

1 Introduction

China has a history of more than 5,000 years and its cultural heritage is profound. Therefore, the ancients have left us with many cultural heritages, which are precious treasures of mankind. Cultural heritage is divided into physical cultural heritage (tangible cultural heritage) and intangible cultural heritage (intangible cultural heritage). The material cultural heritage refers to cultural relics of historical, artistic and scientific value, including historical relics and ancient buildings. Human cultural sites have been preserved to the present, and have become invaluable treasures in China. However, with the passage of time and the influence of human natural activities and the environment, many material cultural heritages have been seriously damaged, especially ancient buildings. The ancient buildings have been exposed to the external environment

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for a long time. They are more seriously eroded by the rain, snow and wind. The outer ones are damaged, broken, and collapsed. They are gradually annihilated in the long river of history. Only the 12th and 2nd ancient buildings survived. The typical is the Forbidden City in Beijing. The Forbidden City in Beijing is the royal palace of the Ming and Qing Dynasties in China. It is located in the center of Beijing's central axis and is the essence of ancient Chinese palace architecture. But the Palace Museum we see now is not the original Forbidden City form, but has been modernized [1]. In order to preserve this great building, the country will invest a lot of money and dispatch professionals to repair the Forbidden City every year. The maintenance of ancient buildings is not a simple task, because the construction of ancient buildings is different from that of modern buildings. Therefore, maintenance must maintain the characteristics of ancient buildings and achieve the purpose of maintenance. The process is more complicated. In this context, the three-dimensional modeling of complex curved surfaces of ancient buildings, the practice of repairing the model on the model, not only can speed up the maintenance efficiency, but also minimize the secondary damage to ancient buildings. The design process of 3D reconstruction model of complex curved surface of ancient buildings is mainly divided into the following three steps: firstly, the LiDAR non-contact is used to obtain the ancient building information, then the information is processed, and finally the 3D reconstruction of the complex surface of the ancient building is completed. In order to ensure the effectiveness of the method, a set of precision simulation experiments are carried out. The results show that the method is more accurate than the other two methods [2].

2 Design of 3D Reconstruction Model of Complex Curved Surface of Ancient Buildings

Figure 1 below shows the design flow of the 3D reconstruction model of complex curved surfaces of ancient buildings.

The three-dimensional reconstruction model design of complex curved surface of ancient buildings is divided into three parts: the acquisition part, using LiDAR to obtain the complex surface LiDAR point cloud data of ancient buildings; the processing part: processing the LiDAR point cloud data and color digital image data; reconstruction Partly, the 3D reconstruction of complex curved surfaces of ancient buildings is completed [3].

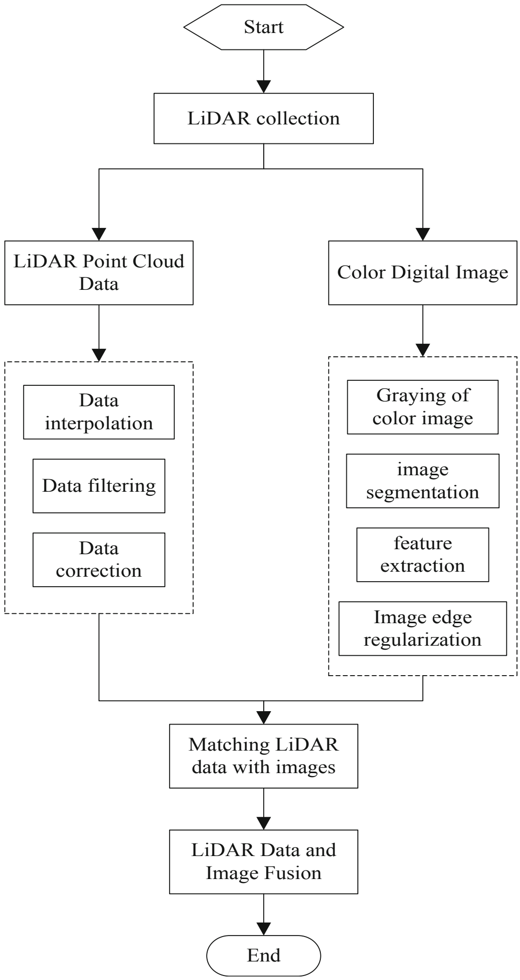

Fig. 1. Design flow of 3D reconstruction model of complex curved surface of ancient buildings

2.1 Acquisition Part

The acquisition part is the basis of the three-dimensional modeling of complex curved surfaces of ancient buildings. The main tool is Lidar, which is called LiDAR in English. The main function is to measure the three-dimensional coordinates of the ground buildings. LiDAR consists of several devices:

(1) The laser scanner is mainly used to measure the relative position and distance between the laser emitter and the ancient building, and to scan the complex surface size and shape of the ancient building;
(2) Digital camera, the main function is to obtain images of ancient buildings, and record spectral information and other related data information;

(3) Inertial Measurement System (INS): The direction in which the laser is emitted and reflected back.
(4) The central control unit, whose main function is to control and manage the operation of LiDAR;
(5) Storage unit, the main role is to save data information [4].

Here, the RB-13K255 LiDAR produced by Harbin Aosong Robot Technology Co., Ltd. is selected. The relevant parameter settings are shown in Table 1 below.

Table 1. RB-13K255 LiDAR related parameter settings

Project	Enhancement mode	Outdoor mode
Applicable scenario	Stronger performance, suitable for indoor environment	Higher reliability, suitable for outdoor environment, reliable anti-sunshine ability
Maximum measuring distance	25 km	
Sampling frequency	200 Hz	
Scanning frequency	15 Hz	
Angular resolution	0.337°	0.54°
Communication frequency	256000 bps	
Communication frequency	Supporting previous SDK/protocols	

RB-13K255 LiDAR works (see Fig. 2): Lift the aircraft above the ancient building, turn on the laser scanner and emit a laser beam (laser, semiconductor laser, etc.). When the laser beam encounters an ancient building, it will follow the launch. The route is reflected back, then received by the receiver in the laser scanner, and the time difference between each laser beam from the emission to the reflection is recorded. Finally, according to the known laser propagation speed, the laser emitter and the ancient building can be calculated. The distance between the specific calculation formula is as follows:

$$d = \frac{1}{2} v \cdot t \tag{1}$$

In the formula, d is the distance between the laser emitter and the ancient building; v is the laser propagation speed; t is the time from the laser beam to the reflection [5].

However, it is not enough to only measure the distance data. In order to build a three-dimensional model of complex surface of ancient buildings, it is necessary to further determine its coordinates. The specific steps are as follows:

(1) The coordinates of each laser reflection point are determined according to the position and direction of laser emission.
(2) The IMU is used to measure the relevant parameters of the aircraft, including heading angle, pitch angle, yaw angle, etc.
(3) Using GPS to measure the space coordinates of aircraft;
(4) The results of step (1) are corrected by steps (2) and (3), and the accurate spatial rectangular coordinates of each laser foot point (each laser beam point on an ancient building) are obtained [6].

In addition, we need to use digital camera to record the color image of ancient buildings, which can provide a reference for the three-dimensional model of complex surface of the latter ancient buildings.

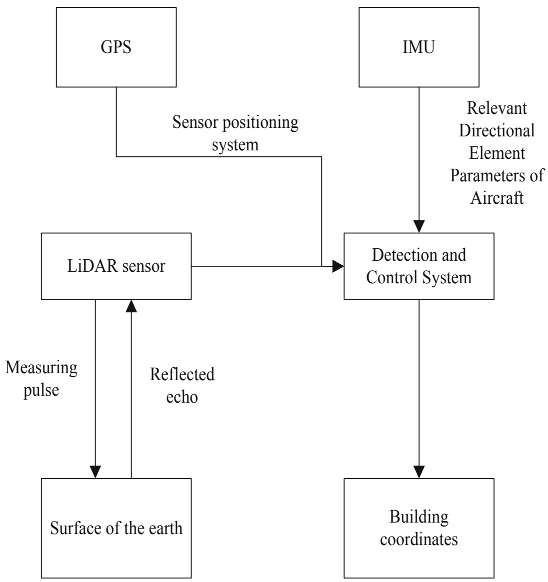

Fig. 2. The working principle of RB-13K255 LiDAR

2.2 Processing Section

In Sect. 2.2, two types of data are obtained, one is LiDAR data, the other is color digital image, so there are two tasks in the processing part.

(1) LiDAR Data Processing
  (1) Data correction: Errors of LiDAR equipment and accidental errors are the main causes of data errors of LiDAR, so before registration with image data, error correction is needed to improve the accuracy of LiDAR data.
  (2) Data filtering. In the process of digitalization of physical scanning, errors, redundant points and measurement noise caused by scanning environment will inevitably be introduced. These points will have a great impact on the later reconstruction of physical model. In order to extract the characteristic data of physical objects better, data filtering must be carried out to remove these errors. There are two commonly used data filtering methods: the first one is based on the abrupt elevation change; the second one is based on the echo intensity of laser foot data. In this section, the second method is used to complete the data filtering task. The principle is as follows: Because the surface of ancient buildings is not smooth, there are intensity differences in the reflected signals. Using this difference, the signals are transformed into corresponding images with different gray values, and then the filtering process is completed according to the operation flow of image filtering method. The process is as follows: the constructed smoothing filter is placed in gray. Roaming over the graded image, then collecting the gray value of each pixel in the image, sorting these gray values according to the sequence from small to large, then finding out the middle value, and finally giving the middle value to a central position pixel in the image [7].
  (3) Data interpolation: After data filtering processing, there will be some empty shortcomings, such as the part below the eaves of ancient buildings which can not be illuminated by airborne LiDAR, so it is necessary to add the elevation of ground points to this position, and then build a complete ground elevation model. The above supplementary process is called data interpolation [8].

(2) Color Digital Image Processing
  (1) Graying of color image. Grayscale image refers to a series of processing of color images with multiple colors to produce corresponding gray images containing only black, white and different shades of gray. There are many methods of image graying, such as component method, maximum method, average method, weighted average method and so on. In this section, the weighted average method is used to gray the image [9]. The basic idea is to assign different weights according to the importance of each component, then calculate the weighted results, and gray the weighted mean. Because the ultimate goal of color digital image processing is to get the smooth edge of the image, the optimal weights of R, G and B are 0.30, 0.59 and 0.11, respectively. This method can be described by the following mathematical formulas:

$$f(i,j) = 0.30R(i,j) + 0.59G(i,j) + 0.11B(i,j) \tag{2}$$

In the formula, R, G and B are the components of three colors. (i,j) is a coordinate pixel in gray image.

(1) Image segmentation. Image segmentation is to segment the object from the whole image. In this paper, the ancient buildings are separated from the background in the image. At present, there are four commonly used segmentation methods: threshold-based, region-based, edge-based and specific theory-based. In this paper, a threshold-based image segmentation method is adopted. Its basic principle is as follows: first, an approximate threshold is selected as the initial value of the estimated value, then the threshold is continuously improved, and finally, a new threshold is used to segment the image.

(3) Extraction of complex surface features of ancient buildings. The feature extraction of complex surface of ancient buildings is to detect the image edges of ancient buildings. Its basic principle is to use image edge enhancement operator to highlight the local edges of the image, then define the "edge intensity" in the image, and then extract the image edge points by setting threshold.

(4) Image edge regularization. The edges of building images extracted from complex surface features of ancient buildings are irregular and serrated, which can not be used for subsequent three-dimensional modeling. Therefore, image edges need to be regularized to make the edges smooth [10].

2.3 Reconstruction Part

The LiDAR data obtained above are matched with the image to synthesize a three-dimensional model of complex surface of ancient buildings. The specific process is shown in Fig. 3 below.

3 Simulation Test Experiment

In order to test the accuracy of this method, a set of simulation experiments is required. The simulation experiment object is an ancient tower building in a certain ancient city. The building has a total of six floors and has a delicate shape. It has existed for hundreds of years, and many of the outer walls have fallen off and are facing the risk of collapse. In order to reflect the superiority of the method, experiments were carried out together with two other three-dimensional model construction methods. That is to say, literature [1] method (method 1) and literature [2] method (method 2) are used to compare with this method. After the modeling is completed, 10 points are selected as the experimental precision test points, and the coordinates in the model are shown in Table 2 below.

It can be seen from Table 2 that the coordinates in the model are almost the same as the real coordinates by using this method. After modeling with the other two methods, the coordinates in the model are quite different from the real coordinates. It can be seen that the modeling accuracy of the method is higher.

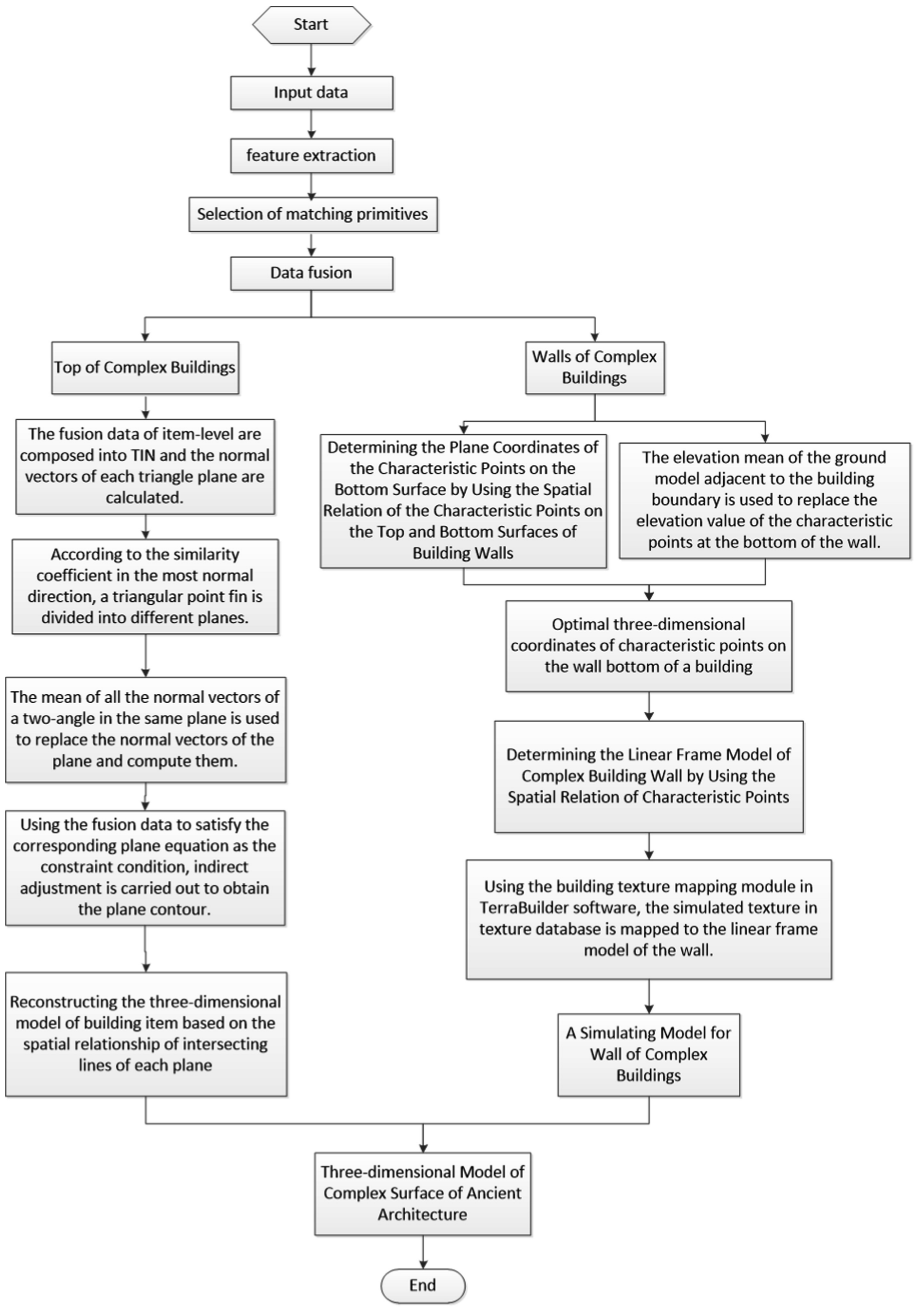

Fig. 3. Construction flow of complex surface three-dimensional model of ancient architecture

Table 2. Comparison of coordinates and real coordinates in the model

Test point	Real result	This method	Method 1	Method 2
1	X = 25.36	X = 25.36	X = 25.56	X = 25.78
	Y = 15.68	Y = 15.68	Y = 15.78	Y = 15.67
	Z = 35.35	Z = 35.35	Z = 35.37	Z = 35.36
2	X = 14.69	X = 14.68	X = 14.98	X = 14.78
	Y = 17.68	Y = 17.67	Y = 17.67	Y = 17.62
	Z = 24.98	Z = 24.98	Z = 24.78	Z = 24.78
3	X = 25.74	X = 25.74	X = 25.78	X = 25.36
	Y = 15.68	Y = 15.68	Y = 15.34	Y = 15.67
	Z = 24.87	Z = 24.87	Z = 24.87	Z = 24.36
4	X = 25.36	X = 25.36	X = 25.36	X = 25.36
	Y = 14.65	Y = 14.65	Y = 14.87	Y = 14.87
	Z = 32.53	Z = 32.53	Z = 32.67	Z = 32.75
5	X = 37.65	X = 37.65	X = 37.78	X = 37.78
	Y = 20.35	Y = 20.36	Y = 20.87	Y = 20.68
	Z = 21.68	Z = 21.67	Z = 21.36	Z = 21.36
6	X = 25.36	X = 25.36	X = 25.85	X = 25.69
	Y = 35.98	Y = 35.98	Y = 35.34	Y = 35.34
	Z = 27.98	Z = 27.98	Z = 27.44	Z = 27.54
7	X = 36.87	X = 36.87	X = 36.78	X = 36.34
	Y = 15.68	Y = 15.68	Y = 15.31	Y = 15.87
	Z = 24.71	Z = 24.71	Z = 24.67	Z = 24.24
8	X = 27.98	X = 27.99	X = 27.87	X = 27.98
	Y = 57.68	Y = 57.68	Y = 57.75	Y = 57.68
	Z = 35.35	Z = 35.37	Z = 35.87	Z = 35.67
9	X = 25.36	X = 25.36	X = 25.36	X = 25.67
	Y = 22.36	Y = 22.35	Y = 22.87	Y = 22.47
	Z = 54.62	Z = 54.60	Z = 54.62	Z = 54.66
10	X = 10.69	X = 10.68	X = 10.87	X = 10.76
	Y = 8.92	Y = 8.92	Y = 8.67	Y = 8.95
	Z = 20.36	Z = 20.36	Z = 20.87	Z = 20.67

4 Conclusion

In summary, China has a long history and profound cultural heritage. History has left us with many material and cultural treasures, of which ancient buildings are typical representatives. As time goes by, ancient buildings have been eroded by natural factors for a long time, and damage has occurred. Therefore, in order to preserve these ancient buildings and protect our history and culture, the restoration of ancient buildings is of paramount importance. Due to the complexity and fragility of the ancient building structure, direct repair is very likely to cause secondary damage to the building. In order to avoid this situation, three-dimensional modeling of complex curved surfaces of ancient buildings is generally carried out before the repair, and pre-repair is carried out on the model. In this context, this paper designs a three-dimensional reconstruction method for complex curved surfaces of ancient buildings based on big data. It is verified that the method has higher precision and can ensure the smooth progress of ancient building repair work.

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