3D Laser Scanning Modeling and application on Dazu Thousand-hand Bodhisattva in China

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ABSTRACT:

The Dazu Thousand-hand Bodhisattva Statue is located at Baoding Mountain in Chongqing. It has the reputation as "the Gem of World's Rock Carving Art". At present，the Dazu Thousand-hand Bodhisattva Statue is basically well conserved, while the local damage is already very serious. However, the Dazu Thousand-hand Bodhisattva Statue is a three-dimensional caved statue, the present plane surveying and mapping device cannot reflect the preservation situation completely. Therefore, the documentation of the Dazu Thousand-hand Bodhisattva Statue using terrestrial laser scanning is of great significance. This paper will introduce a new method for superfine 3D modeling of Thousand-hand Bodhisattva based on the high-resolution 3D cloud points. By analyzing these 3D cloud points and 3D models, some useful information, such as several 3D statistics, 3D thematic map and 3D shape restoration suggestion of Thousand-hand Bodhisattva will be revealed, which are beneficial to restoration work and some other application.

1. INTRODUCTION

The Dazu Thousand-hand Bodhisattva Statue is the China's largest three-dimensional cliff-carved statue that combines sculpture, clay sculpture, gold foil painting and colored drawing together [1]. The standing height is about 7.7 m, and the width is about 10.9 m; the frontal projected area is about 84m2 and the total curved surface area exceeds 210m2. The major bodhisattva statue in the center is caved with thousand hands holding different dharma-vessel, and is known as "the world treasury of stone-carving art" [2]. It has very high historical, scientific and artistic values. Generally speaking, the Dazu Thousand-hand Bodhisattva Statue is well preserved, though local destruction is very serious. Therefore, it is of great significance to document its present situation.

Over the years, the efforts to record the Dazu Thousand-hand Bodhisattva Statue can be divided into two categories: one is the surveying and mapping of its basic morphology and the other is image recording. The surveying and mapping of its basic morphology mainly involves traditional tape measurement, level measurement, total station measurement, optical close-range photogrammetry, digital close-range photogrammetry; image recording mainly includes sketch, traditional film photography (black & white and color photography), digital photography and DV recording[3, 4, 5]. However, the 3D carved statue of Thousand-hand Bodhisattva is complex in structure, so its morphology, structure and preservation condition cannot be reflected by plane and facade surveying and mapping completely and realistically with the following limitations: information retention is neither complete nor realistic; failure to perform disease investigation, quantitative statistics and assessment of high precision; failure to provide accurate data for protection and preservation; failure to provide reliable basis for restoration or virtual rehabilitation.

Recent advances in terrestrial laser scanning technology allow us fast and efficient collection of 3D coordinates of cultural heritage object automatically [6]. Different techniques and principles are used to determine the 3D coordinates of cultural heritage objects with the terrestrial laser scanning systems. In the phase comparison method, the transmitted laser beam is modulated by a harmonic wave, and the distance is calculated based on the phase difference between the transmitted and received wave [7, 8]. Triangulation scanners are based on the optical triangulation method. The transmitting device sends a laser beam on the surface of object and the CCD camera detects the laser beam at the other end of the base. A 3D coordinate of laser beam on the object surface is derived from resulting triangle. The scanning system based on triangulation method is another system that allows the measurement up to a few meters, and accuracy within a few micrometers can be achieved [9]. The triangulation scanner systems are suitable for precise scanning such as sculpture in cultural heritage documentation [10].

The Cimecore and Romer belongs to high-definition terrestrial laser scanner, which is a kind of new high-tech mapping technology using 3D laser radar to acquire 3D point coordinates and gray information of a certain target space. It obtains 3D coordinates of the surface of the target in an automatic, systematic and quick (quasi-real time) way using laser scanning device. As a measurement method of high definition, its precision of single-point positioning can reach the millimeter level. The information retention and fine 3D reconstruction of the Dazu Thousand-hand Bodhisattva Statue

based on Cimecore and Romer has important significance in the following aspects: to realize realistic and complete recording of the present situation; to aid in comprehensive investigation and assessment over the preservation condition; to give virtual restoration effect for on-site restoration; to provide the basis for comparative analysis before and after restoration and future restoration.
The primary objective of this paper is to investigate the basic procedure and application for fine 3D reconstruction for documentation of cultural heritage. The following section 2 will introduce the basic procedure. The experimental studies that are presented in Section 3 provide the technical information about new methods regarding documentation process to explain methodology and the most suitable approach from data acquisition to final product. Several application of are discussed, and technical aspects of new methods used for cultural heritage documentation are assessed.

2. BASIC PROCEDURE FOR FINE 3D RECONSTRUCTION

2.1 Overall process

The basic procedure and application for fine 3D reconstruction for documentation of the Dazu Thousand-hand Bodhisattva Statue is shown in Figure 1.

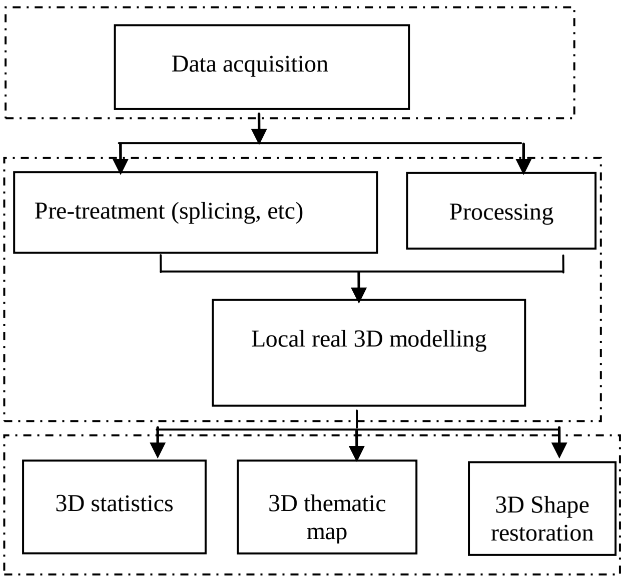


Figure 1. Flowchart for fine 3D reconstruction

2.2 Data collection

Portable scanning machine (CIMCORE Infinite 2.0) is used for high-precision 3D scanning just as follows. (1) Field reconnaissance: to check whether the stability and on-site space can satisfy the requirements of instrument installment; carry out reconnaissance over installment positions. (2) Field preparation: including field reinforcement, preparation for marked drawings of the area to be scanned, and planning the scanning sequence. Field reinforcement is required because the 3D scanning instrument requires high stability of the site. Especially for high-precision scanning instrument, even slight shaking will affect data quality. The scaffold structure used on site has to be reinforced in case of shaking; marked label drawings for the area to be scanned are prepared for the purpose of scanning sequence planning as well as the labeling and archiving of the data scanned. (3) Instrument assembly and calibration: instrument installment and data line connection; instrument calibration after startup. Instrument assembly and calibration on site is necessary as long-distance transportation and handling may affect the precision of the instrument. (4) Single-station scanning: to scan all single hand or area (referring to one certain area of the major bodhisattva). The instrument operator and data receiving personnel shall cooperate closely to ensure that the point cloud scanned has the desired density and coverage. When all single hands of the control area are scanned, a general scanning of the entire area within the control area is performed, and fine scanning is required for places with distinctive characteristic points, for the convenience of splicing of sing hand data. If multi-station scanning is required, the layout and measurement of the control points should be undertaken for data splicing among multiple stations.(5) Data storage and inspection: data should be stored immediately after the completion of the scanning of each single hand or a certain area. Then data inspectors will check the data for the integrity of the data and to see if the data are layered. The qualified data should be classified and stored as files that are named by the number of single hand or the area scanned. Additional worker is required to do field recording, including the results of data inspection and marking of drawings for the area scanned. (6) Complementary scanning: if the data are found to have the problems described above, the scanning personnel shall repeat the scanning until the data are qualified.

2.3 Point cloud disposal

3D point cloud disposal consists of the following steps: (1)Point cloud data check: Because of data occlusion in the scanning process, data loss may be avoidable, and the scanning of external conditions may cause data layering. Thus, data check in the point cloud data pretreatment is one indispensable step, and only 3D software used in industry measurement is available for data check as there is no professional software currently. (2) Gross error culling: As mentioned above, the original point cloud data contains a large amount of gross error, errors and irrelevant information, for which the correction and treatment mainly rely on artificial interactive operation. In the interactive editing environment, the gross error and irrelevant information are culled interactively, and the systematically missing information are complemented. (3) Point spacing measurement: Point spacing measurement refers to the measurement of the shortest distance in space between two adjacent points in point clouds by manual sampling using 3D software. The plane positions are selected for spacing measurement as the morphology of the hands of the bodhisattva varies greatly. (4) Model splicing: The directly output data from 3D laser scanning are based on the local coordinates of the coordinate system used at the survey station. To acquire the 3D model of void statue, the point cloud data acquired from different angles should be spliced by means of information overlapping, which is to incorporate point cloud data acquired at different stations into one coordinate system of a particular station. This process is called model splicing. (5) Unification of the reference system: The unification of the reference system is the premise for subsequent data processing and analysis. According to the characteristics of The Dazu Thousand-hand Bodhisattva Statue, the data from all stations are incorporated into an independent coordinate system. (6) Data simplification: 3D scanning data contain so much redundant data, which are of little use for model establishment or feature extraction. so it is very necessary to select or design proper algorithm to simplify the point cloud data. The data simplification method adopted in this project is to merge and resample the areas concerned.

2.4 3D fine modelling

3D fine modelling consists of the following steps: (1) Boundary definition: Open the scanning files and delete the data according to boundary. (2) Point cloud segmentation: First, choose the region to be segmented from the original point cloud data; save as two files after the segmentation is completed, in order to facilitate data processing with satisfactory results. (3) Point cloud denoising: The data obtained from a laser scanner are 3D coordinates in the coordinate system of the instrument, which are discrete no-attribute "point cloud data". Since these point cloud data contain a large number of gross error and system error due to local jump change data, occlusion frontal data and local void resulting from the lack of echo information, they cannot be used directly. T (4) Unified sampling: The point cloud data collected contain a great number of redundant information from repeated scanning, which requires unified sampling using 3D software before fine modeling. The spacing between the sampling points should be less than 0.1 mm. (5) Building of triangle network model. Triangle network model is built based on the actual volume of point cloud data. For a medium-configuration computer (4G memory), the triangle number between 4 million and 8 million can produce the optimal results. (6) Void filling: Because of the incompleteness of data scanned, void will inevitably appear in the course of modeling, so void filling is necessary. During this process, curved surface is used to fill the void and other operations such as bridging is implemented depending on the specific situation. For the voids associated with warped gold foil, the warping effect must be reflected by void filling. Partial filling method is enough for the near-plane edge of gold foil close to preserve the original state to the maximum extent.

3. EXPERIMENTAL SECTION

The experimental section focuses on the documentation of the Dazu Thousand-hand Bodhisattva Statue, using the Cimecore and Romer of terrestrial laser scanning to give details about procedures and the most suitable approach from data acquisition to final product for each method.

3.1 Scanning

The investigation involving the documentation of the Dazu Thousand-hand Bodhisattva Statue was attempted by Beijing University of Civil Engineering and Architecture, the Chinese Historic Cultural Research Institute, Beijing Digsur Company in 2010. The scanning survey were performed with Cimcore and Romer from Hexagon(shown in figure 2). After data acquisition, all scans were registered onto the reference coordinate system using reflectors in the scan area and its measured coordinates with 0.01 mm accuracy.

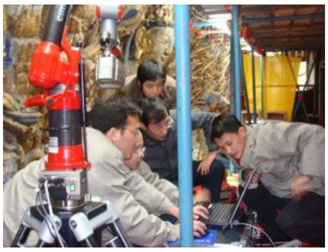


Figure 2 Data acquisition using Cimcore

3.2 The holistic data of Dazu Thousand-hand Bodhisattva Statue

With the high precision scanner Cimcore and Romer，all the data we got was 380G. The holistic data of Dazu Thousand-hand Bodhisattva Statue was shown in Figure 3.

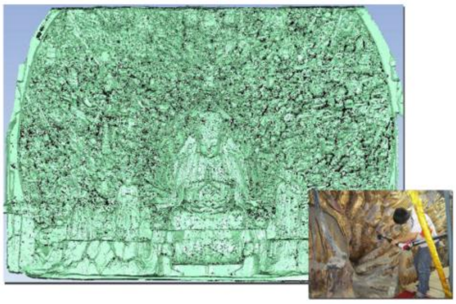


Figure 3 The holistic data of Dazu Thousand-hand Bodhisattva Statue

3.3 The fine 3D model

Based on the fine 3D cloud points from the Cimcore and Romer，the fine real 3D model of the Dazu Thousand-hand Bodhisattva Statue can be constructed, which has the real size and texture. It can be used to make facade and profile maps, which can be directly used in AutoCAD to measure the size, and to extract the real data information. Thus, the Dazu Thousand-hand Bodhisattva Statue can be completely and permanently preserved in its current condition. Figure 4 will show the different model of one hand of the Dazu Thousand-hand Bodhisattva Statue.

Figure 4 Different model of the hand

4. APPLICATIONS

4.1 3D statistics

The investigation involving the documentation of the Dazu Thousand-hand Bodhisattva Statue was attempted by Beijing University of Civil Engineering and Architecture, the Chinese Historic Cultural Research Institute, Beijing Digsur Company in 2010. The scanning survey were performed with Cimcore and Romer from Hexagon(shown in figure5). After data acquisition, all scans were registered onto the reference coordinate system using reflectors in the scan area and its measured coordinates with 0.01 mm accuracy.

Can you guess how many hands there are in Dazu Thousand-hand Bodhisattva stature? According to the historic record, there were exactly 1000 hands at the beginning. So it's called Thousand-hand Bodhisattva. Actually, right now according to the 3D model and the details, there are only 830 hands in the holistic Dazu Thousand-hand Bodhisattva stature.

The restoration work needed the data of restoration work area in 2013. So based on the fine 3D model, several statistic could be processed. Just as the following Figure 5 shows. The total restoration area in 2013 is 38.08 m^2.The colorful paints area of instruments held by the hand is 2.98m^2, and the gold foil area is 35.1 m^2.

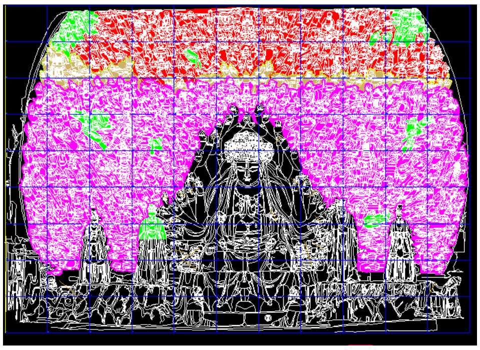
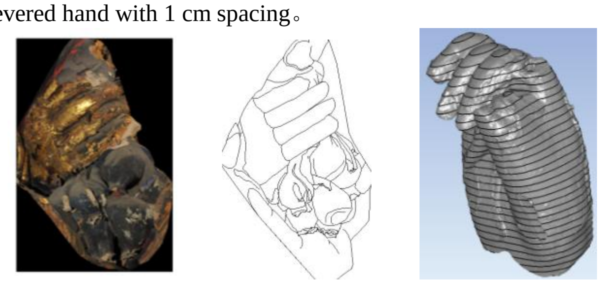


Figure 5 The red area is the restoration area in 2013

4.2 3D thematic maps

The fine 3D model can be used to produce 3D thematic maps: orthophoto map, digital line graph, and contour map, just as Figure 6 shows. Figure 6(c) shows the contour map for the severed hand with 1 cm spacing。



(a) Orthophoto map (b) digital line graph (c) contour map

Figure 6 3D thematic maps

4.3 3D shape virtual restoration

For the purpose of helping archaeological studies and cultural relic protection project, 3D shape virtual restoration is so important. By comparison with the virtual restoration effect, the real restoration effect could be evaluated. Figure 7 shows the effects of 3D model effect of no restoration, virtual restoration and real restoration.

Before restoration Virtual restoration After restoration

Figure 7 Virtual restoration

5. CONCLUSION

This paper discusses the fine 3D modeling technology and several applications for the Dazu Thousand-hand Bodhisattva Statue with Cimecore and Romerand, with the main work as follows: 1. retain complete and accurate information of the entire bodhisattva statue as historical material for permanent archiving; 2. original data pretreatment; set up the fine 3D model of all targets and build basic models for later applications such as virtual restoration or digital display; 3. measure the basic data accurately from the established 3D fine model to provide basic information and related maps for actual restoration, including area, volume, damage rate, etc.; 4. carry out virtual restoration according to the established 3D fine model to provide reference for actual restoration; 5. establish digital display system of The Dazu Thousand-hand Bodhisattva Statue; 6. carry out tracking and monitoring over the restored 3D morphology of the Dazu Thousand-hand Bodhisattva Statue.

3D laser scanning technology is the optimal approach available to retain and extract the original real information of stone statues. As a representative of extremely complex 3D target, the collection of the 3D information of the Dazu Thousand-hand Bodhisattva Statue, its mass data processing and application research cover extensive contents. The subsequent work will mainly focus on data management and application of the massive point cloud data of The Dazu Thousand-hand Bodhisattva Statue.

6. REFERENCES

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