Ancient Architecture of 3D Digital Modeling and Virtual Simulation Technology

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Abstract — For China's brilliant ancient architecture, China needs to use modern information technology for the protection and development. First of all, the establishment of an ancient general component library system framework. Ancient building surveying and mapping, and then research the drawings as a starting point, the semantics of the ancient architectural drawings entity elements, dimensioning semantics, implied semantic description method of the schema information for related parameters. In turn, this parameter is known as the three dimensional structure of 3 d component libraries, so as to realize the rapid reconstruction of ancient building 3 d project model. At the same time, based on the clustering characteristics of planar point cloud data to streamline algorithm and basic voxel reverse projection reconstruction algorithm based on 3 d coordinates. Finally through a concrete building modeling practice prove that this method is effective, and can be more accurate, simple and convenient.

Keywords - ancient building; 3D modeling; component libraries; data reduction

I. INTRODUCTION

Ancient architecture not only has a high historical value, artistic value, also has a high scientific value, material evidences of science is the study of history, is also a new important reference architecture design and new artistic creation, many ancient buildings, gardens, etc. are an important part in cultural tourism. The study of ancient buildings and 3 d digital modeling technology is a very important cause. Due to wind and rain erosion, such as the impact of natural factors and human factors such as tourism development, these old historical and cultural heritage with the passage of time is experiencing considerable damage, must be relatively closed management and repair, to reduce the natural factors, especially in human factors to have the further damage of the damaged of precious relics and antiquities. To spread throughout the world, on the other hand, and promote the cultural tourism value contained in the ancient buildings, and who must be with an open attitude to meet a lot of tourists from home and abroad, the implementation of the open, interactive display.

With the continuous development of modern information technology, new technology, and how to use these new technologies for the development and protection of the ancient buildings become an important research topic, and got good grades. Through recognition of the corresponding to the body of revolution in research from the view of matching sequence, the method of using the axial alignment of ancient architecture of 3D model reconstruction [1]. Research involving human tissue structure topography, buildings, vegetation, urban areas, such as a wide range of target, according to different target USES a variety of different methods of three dimensional space information acquisition and modeling method, have sprung up 3 d model reconstruction based on surveying and mapping engineering diagram, parameterized based on engineering semantic reconstruction, 3D reconstruction based on two-dimensional digital image, based on laser scanning point cloud data of 3D reconstruction, 3D reconstruction based on structured light, multi-source data fusion of three-dimensional heavy, etc. [2]. Established by three view drawing reconstruction polyhedron bottom-up algorithm of formal definitions, theorems and proofs, for the first time, better solve the issue of multiple solution and pathological solution algorithm in each step to detect and remove the false yuan, involving a large number of projection and combination search, high computing complexity [3]. By comparing the average distance between point to point in a limited space value method to judge the size of the point cloud density size, so as to decide whether to need to delete the redundant data points, put forward a streamline method based on the average point distance. This method is applicable to a large number of scattered three-dimensional point cloud data to streamline, its shortcomings is a bigger point cloud data points density change effect is poorer [4].To streamline the data using spline curve fitting method, the principle of this method is small curvature area has reserved a small amount of points, while large curvature area reserved enough points, expressed as a precise full surface characteristics. This method can accurately maintain the surface characteristics and effectively reduce the data points, but generally low computational efficiency [5].

Obviously, our current research is still stay on the case study of ancient architecture, not the paper summarizes the model of the ancient buildings, ancient architecture and implementation from the perspective of computer technology of modular modeling. This is what we are trying to research direction. The total trend of domestic and foreign research is the study of a relatively general 3 d digital modeling software, put forward this topic has the positive significance. In this paper, the second part introduces the subject required by the relevant technology and the final formation of the technical route. The third part has carried on the experiment
and the results of technical route data analysis. The fourth part is a summary of full text research results and induction.

II. MATERIALS AND METHODS

A. Ancient Buildings Commonly Used 3D Component Libraries

Ancient Chinese architecture, especially in the Ming and Qing dynasties, had an ancient appearance with primitive simplicity, gorgeous, complicated structure, but it abides by the rules of a certain shape. In order to improve the engineering structure 3D model reconstruction in the fourth chapter, it details the efficiency of the commonly used 3D component libraries need to build ancient buildings.

China's ancient buildings, generally can be divided into the imperial government buildings, defensive guard ten types, etc. [6].

<table>
<thead>
<tr>
<th>type</th>
<th>building</th>
</tr>
</thead>
<tbody>
<tr>
<td>Imperial government buildings</td>
<td>The palace, halls, mansions, etc.</td>
</tr>
<tr>
<td>Defensive guard building</td>
<td>Walls and towers, the Great Wall, etc.</td>
</tr>
<tr>
<td>Memorial building ornament</td>
<td>Bell tower, drum tower, bridge gallery, etc.</td>
</tr>
<tr>
<td>The mausoleum building</td>
<td>Network, cave tomb, daish, etc.</td>
</tr>
<tr>
<td>Gardens building</td>
<td>The palace, palace bounded, garden, villa, etc.</td>
</tr>
<tr>
<td>Sacrifice sexual building</td>
<td>Confucian temple, guanyue tower, etc.</td>
</tr>
<tr>
<td>Bridges water conservancy construction</td>
<td>Stone bridge, bridge, ports, docks, etc.</td>
</tr>
<tr>
<td>Local-style dwelling houses building</td>
<td>Cave, hut, court hall, courtyard, etc.</td>
</tr>
<tr>
<td>Religious buildings</td>
<td>Temple, view, mosque, the chapel, etc.</td>
</tr>
<tr>
<td>Entertainment building</td>
<td>Music, dance floor, stage, terrace, stands, etc.</td>
</tr>
</tbody>
</table>

TABLE 1: THE MAIN BUILDING TYPE IN ANCIENT CHINA

Ancient Chinese architecture system is given priority to with timber frame construction, from the perspective of the size of the building, flat, elevation layout of the building to meet is the basic principle of symmetry, rules, and the change of mass and stiffness [7]. In Beijing the imperial palace, for example, its overall layout is along the north-south axis vertical arrangement, to Tiananmen square, temple outside the three as the climax, Jingshang temple tail, both from the Lord, and before and after the echo, coherent whole, is a good example of Chinese palace architecture.

Ancient buildings in various forms, but the proportion of each part has a relatively fixed relation, is also keep the various forms of building unified style of the important principles. Individual buildings according to certain standard, the basic building blocks assembled, ancient architecture is established beforehand and 3D standard parts library can greatly speed up the ancient architectural engineering structure model reconstruction.

3D digital model is including wire frame model, surface model and solid model. Among them, the wireframe model geometry shape, just using the geometry of the ridge said no surface in the model, size and other information [8]. Surface model is the outer surface of the geometry model, like the wireframe model on a layer of skin, make geometry has a certain profile, can produce effects such as shadow, blanking, but lack of geometry in the model the concept of volume, like a empty shell of geometry. As in the middle of the geometry entity model filled with a certain material, make it has the characteristics such as weight, density, and can check the two geometries of collision and interference, etc [9].

B. Parameterized Ancient Architecture Engineering Structure 3D Model Reconstruction

According to surveying and mapping engineering drawing for engineering semantics, thus building type, and obtain a pipe mouth modulus, stylobate style, roof truss structures and main parameters of roof components, and parameter called 3D component library of 3D component to the corresponding position of reconstruction of 3D architectural graphics, hierarchical complete rapid reconstruction of ancient building 3D project model. The reconstruction of the main steps is shown in figure 2.

Figure 1 Panoramic view of the Forbidden City

Figure 2 Parameterized ancient architecture engineering structure diagram of the 3D model reconstruction

Reconstruction process: determine the architectural form and modulus, order parameter, roof and roof parameters.
C. Ancient Building Large Scattered Point Cloud Data Of 3D Reconstruction

Most of existing buildings has experienced hundreds or even thousands of years of time change, due to the wind, rain, lightning, earthquake and other natural factors and human factors such as tourism development, the influence of different level there is a serious deformation and breakage [10]. The traditional manual scale, such as benchmarking method measurement, measurement accuracy is low, not only to climb higher artifacts measurement will cause further damaged cultural relics. Three-dimensional point cloud data is the use of 3 d scanning device was carried out on the building surface scanning, 3D coordinate points for the structure of the surface data.

1) To get point cloud data

Building 3D data acquisition using ranging scope biggest 3 d laser scanner based on pulse type, outdoor measurement is not affected by ambient light [11]. 3 d laser scanner through continuous fast point measurement of horizontal and vertical direction, the surface measurement, also said that the space in polar coordinates into the specified horizontal and vertical interval, and then quickly measuring the distance grid intersection point, then to calculate the spatial coordinates of point through Angle.

![Figure 3 The coordinates of 3D laser scanning system - the right hand the Cartesian coordinate system](image)

Through data collection objects ranging observation value S, precision clock synchronization control encoder measuring each azimuth Angle (α) and elevation Angle of the laser pulse (β), can get the 3D laser point coordinate calculation formula is as follows.

\[
\begin{align*}
X &= S \cos \theta \cos \alpha \\
Y &= S \cos \theta \sin \alpha \\
Z &= S \sin \theta
\end{align*}
\]

Point cloud data to streamline the commonly used methods

2) Uniform grid compaction

Step 1 In perpendicular to the plane of the scanning direction, establish a series of uniform small squares every scan point is assigned to a grid.

Step 2 Calculate the point d the distance to the grid, according to the distance size all data points assigned to the same square.

Step 3 Distance is located in the middle value of data points representing all assigned to the grid of data points, the other point is deleted.

Uniform grid method can well is suitable for single piece of data on the surface of the scanning direction vertical scanning, but to have stitching the three-dimensional point cloud data of the effect is not ideal.

3) The average distance value compaction

According to the limited space, the greater the density of point cloud, the average distance between point and point value [12]. Literature by comparing both distance between point to point in a limited space value method to judge the size of the point cloud density size so as to decide whether to need to delete the redundant data points. The main steps for algorithm

Step 1 Define the sampling set square side length d and the percentage to simplify data point Φ two parameters.

Step 2 Define the average distance cube.

Step 3 Calculate P Q i inside the distance of any point to point set.

\[
|PQ| = \sqrt{(P_x - Q_x)^2 + (P_y - Q_y)^2 + (P_z - Q_z)^2}
\]

Step 4 Ask the average distance.

\[
\bar{D} = \frac{\sum |PQ|}{n}
\]

Step 5 According to user defined data Φ lean percentage, the minimum percentage of the average distance value data points to delete, so as to realize the streamline of point cloud data.

This method is applicable to a large number of scattered three-dimensional point cloud data to streamline, its shortcomings is a bigger point cloud data points density change effect is poorer.

4) Based on the clustering characteristics of planar point cloud data to streamline algorithm

3D coordinate points as the main form of 3D vector data, is to build the basic elements of space geometry object, analyses all kinds of vector space judgment and operation is also the object directly [13], so the 3D point coordinates the representation of data effectively and simplify, called a three-dimensional point cloud data of the important goals of the research and utilization, based on 3D reconstruction of point cloud data has very important practical significance.

Firstly calculates the smallest rectangle that contains all data space, the I, J, K, respectively the cube space length, width and height.

\[
\begin{align*}
I &= \text{ceil}(X_{\max} - X_{\min}) \\
J &= \text{ceil}(Y_{\max} - Y_{\min}) \\
K &= \text{ceil}(Z_{\max} - Z_{\min})
\end{align*}
\]
Among them (Xmin, Ymin, Zmin) minimum coordinate of the rectangle bounding box for the space (Xmax, Ymax, Zmax) for the maximum coordinates rectangle bounding box. Algorithm will be surrounded by cube box of the coordinates of the maximum and minimum values using global variables to store. Between () is to take up the whole function.

Then, calculate the son of the cube. A child of the cube is for H.

$$H = \text{ceil}(BK / n)$$  \hspace{1cm} (5)

D. A Single Image 3D Reconstruction of Ancient Buildings

With the wide use of digital cameras and more and more cheap price, use a digital camera to obtain images of the structure of the 3D measurement and reconstruction is also one of the research hotspots and difficulties in ancient architecture protection technology.

Vanishing point based on geometric relations, can use the vanishing point image of common digital camera calibration, and obtains the camera interior orientation parameters and Angle parameters, to restore 2D images of 3D scene [14].

Coordinates transformation relationship

$$Z = \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} = \begin{bmatrix} u/\gamma \ 0 \ 0 \ 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix} = \begin{bmatrix} f \ 0 \ 0 \ 0 \ \gamma \ 0 \ 0 \ 0 \ \gamma \ 0 \ 0 \ 0 \ \gamma \ 0 \ 0 \ 0 \ \gamma \ 0 \ 0 \ 0 \ \gamma \ 1 \ 1 \ 1 \ 1 \ 1 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$  \hspace{1cm} (6)

Which matrix K is related to the internal structure of the camera only called camera intrinsic orientation parameter. Among them, fu, fv horizontal axis and vertical axis for the image scale factor; γ for lens distortion factor, it is a reflection of u and v direction is not strictly vertically, in photogrammetry, generally do not consider this case, please think it to 0. (u₀, v₀) is as the main points in the image coordinate system of the coordinate. R and T for the position of the camera relative to the world coordinate system and the direction referred to as the camera exterior orientation parameters. R by images of three the rotation of the rotation Angle of direction cosine matrix, Tx, Ty, Tz as the center of photography in the coordinates of the object coordinate system component. Matrix P = K[R, T] called a perspective projection matrix.

Set according to the type (6), expressed as a homogeneous coordinate space coordinate system for Si (Xᵢ, Yᵢ, Zᵢ, 1), zero for si (xᵢ, yᵢ, 1), projection matrix p for 3 line 4 columns of homogeneous matrix, in the perspective of from three-dimensional space to two-dimensional images of perspective projection can be expressed as follows.

$$\begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} X_i \\ Y_i \\ Z_i \\ 1 \end{bmatrix}$$  \hspace{1cm} (7)

In the projection matrix p 11 degrees of freedom can be decomposed into the rotation of the camera relative to the space coordinate system matrix R, T and translation matrix of a camera calibration matrix K.

$$p = MK[1 \ 1^{-1}P] = KR[1 \ 1^{-1}C] = K[R \ T]$$  \hspace{1cm} (8)

In perspective projection and projection plane un-parallel converge in a little after a set of parallel projection, which is called the vanishing point. The vanishing point can have an infinite number. After the introduction of three-dimensional space rectangular coordinate system, and three axis parallel to the direction of vanishing point called vanishing point, there are three most main vanishing points.

III. RESULTS

We small wild goose pagoda ancient building group as an example to for us to establish the basis for clustering characteristics of planar point cloud data to streamline algorithm, and comparing with the original algorithm. Experiment object for the tower body of the site of the small wild goose pagoda area, including the tower, Kentucky and the tower before the tablet, the scene of point cloud data is 20141367 Points. Based on the realization of the aim of site scene of 3D virtual display, in this paper, the main evaluation criteria to determine as point cloud model simplified geometric integrity and visual sense of reality [15].

For the main operating processes.
First, the file type conversion. Second, reading point cloud data. Third, compare the result of the streamline.

<table>
<thead>
<tr>
<th>K</th>
<th>File Size before Streamlining (kb)</th>
<th>Streamlining File Size (kb)</th>
<th>Streamline Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>14088</td>
<td>7</td>
<td>The outline is clear, surface features in good condition</td>
</tr>
<tr>
<td>3</td>
<td>2034</td>
<td>79.9%</td>
<td>Keep the outline and main details</td>
</tr>
<tr>
<td>11</td>
<td>773</td>
<td>94.5%</td>
<td>Can identify outline, partial loss of detail features</td>
</tr>
<tr>
<td>50</td>
<td>171</td>
<td>98.7%</td>
<td></td>
</tr>
</tbody>
</table>

![Figure 4: And smaller than a smaller file size before and after the change](image)

At the same time, along with the increase of k value, in the region of the building surface smooth, compact effect is good, in the region of the curvature change dramatically, streamlined data details will be lost, when weighing the smaller rate and keep rate details can choose according to need to k value. And adopt the way of reconstruction, can
make use of symmetry of the building, the restoration of body parts.

In view of the ancient building three-dimensional virtual display for this specific application can choose lean rate high, the details through texture mapping to make up for good. This algorithm made a reservation in the effective under the premise of architectural style and detail characteristics, the ancient building to the point cloud data efficiently simplify the processing, can effectively reduce the size of the point cloud data to ancient buildings quickly establish foundation for 3D model.

IV. CONCLUSIONS

Digital 3D reconstruction of old buildings has been a hot research topic in the field of protection, thus has broad research prospects. However, relative to the ancient China's advanced construction technical achievement, is still relatively backward in the modern information technology in China, has yet to fully reflect the modern technology to protect and develop the enormous function, thus to carry on the exploration and research in this field, not only to the cultural relics, ancient buildings, monuments and other repair and restoration work provide the basis of detailed and accurate, engineering data to reduce people's physical contact and at the same time, increase understanding of the details and the virtual ground to recover the original appearance of building sites, can dynamically simulate the evolution from the ancient and, for archaeological research and tourism information more vivid expression. This is also in this paper we study the motivation and purpose.

This paper mainly studies the reconstruction of the ancient buildings under the condition of different data. In establishing modular three-dimensional component library, on the basis of first puts forward the model of ancient architecture engineering based on 3D component libraries 3D reconstruction, the establishment of a high precision and engineering buildings three-dimensional digital model of the three-dimensional model, not only retained the ancient architecture engineering structure relations, for the cultural relics, ancient buildings, monuments and other repair and restoration work provide the basis of detailed and accurate, engineering data, also available for archaeological research of technical and artistic characteristics of ancient buildings, and the project simulation, such as disaster prevention research. According to ancient building group of point cloud data simplification problem, put forward the clustering characteristics of planar data reduction algorithm is proposed. To achieve high reduction ratio, and in the small wild goose pagoda to the reconstruction of point cloud applications, has a good modeling effect. Early for some buildings only image data, and large quantities of ancient building surveying and mapping and the needs of the texture space reconstruction rapidly, this paper presents a two-step compound calibration algorithm, and applies this method to complex 3 d reconstruction, achieved good results. Although in this paper, the 3 d reconstruction of ancient did some research work, but some problems still remains to be further in-depth study. We need to further research to establish parametric component library, input component parameter according to actual needs, to meet the need of practical 3 d modeling of ancient, and how to automatically accurately extract the parallel lines in the images of the scene and the Lord is also a subject to solve the problem, and how to acquire the method of data fusion in a variety of ways.

REFERENCE


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