

Application of 3D Digital Modeling and Virtual Simulation Technology in Ancient Architecture

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Abstract: In order to understand the application of three-dimensional digital modeling and virtual simulation technology in ancient buildings, this paper will carry out relevant analysis. Firstly, the Chinese ancient buildings and the "Construction Formula" are analyzed. Then, the three-dimensional parameter modeling method is elaborated. Finally, the application of the model is deepened through virtual simulation technology, and verified by a case. The results show that three-dimensional digital modeling can form a scaled stereo model according to the parameters of ancient buildings. The model has complete structure, perfect details, clear boundary, and can visually see the various components of ancient buildings. Combining with virtual simulation technology, the model can be restored. Both of them have high application. Value. As a representative form of Chinese traditional culture, ancient buildings have been gradually damaged and reduced under the erosion of the historical river. For the purpose of cultural inheritance and protection, we should complete the restoration of damaged ancient buildings. To achieve this, we should adopt three-dimensional digital modeling technology and virtual simulation technology. You can get tremendous help. Through three-dimensional digital modeling and virtual simulation technology, the ancient building model can be displayed perfectly.

1. Introduction

China is an ancient civilized country with 5000 years of culture. With the change of dynasties, how many civilizations and brilliance have been nirvanated in the long history, but also left many cultural heritage, among which the ancient architecture is the representative. Chinese ancient architecture has outstanding achievements and unique style, and occupies an important position in the world architectural history. Architecture of each dynasty in China has its own characteristics, and has important cultural and historical connotations and cultural heritage protection value. Ancient architecture is the combination of science, technology, culture, knowledge and art. It is also an important historical carrier. To protect ancient architecture and cultural relics is to preserve history. Today, with the development of high technology, we must explore diversified ways of protection, in which digital protection is the embodiment of new thinking and new methods. With the wide application of computer technology, how to digitally model ancient buildings and virtual simulation protection has become a new research field. At present, the research is mainly focused on the case modeling and animation demonstration. How to use parametric modeling for ancient buildings is an important research topic.

The Building Formula realizes the modularization of Chinese ancient architectural design standards and provides a parametric basis for three-dimensional modeling. By studying the characteristics of three-dimensional model of ancient buildings, taking Dougong as the representative, and combining with the parametric design method based on the construction process, the parametric modeling method of ancient buildings is systematically put forward.

2. Ancient Chinese Architecture and "Building French Style"

The most important feature of Chinese ancient architecture is the form of wood structure, especially Dougong, which represents the architectural characteristics of China. According to the stress characteristics of timber and the aesthetic concept of the working people, it is a composite

component created by many laborers, which is composed of a series of wooden components interlaced vertically and horizontally and overlapped layer by layer. It undertakes the functions of overhanging eaves, supporting beams, decorating under eaves and displaying grades in ancient Chinese architecture, accompanied by ancient Chinese architecture. Development and development. Its position in Chinese architecture is the change of order (column type) in Greek and Roman architecture, and the change of duo-gong, which is also the change of Chinese architecture. The influence of Jew Order on European architecture is of the utmost importance. The structure and structure of Chinese ancient buildings, regardless of the method, material, shape, material size and so on, are mainly determined by the "French", "practices" and "customization" used at that time. There are roughly two kinds of technical specifications used by architects. One is officially promulgated, such as the Song Dynasty's "Building French Style", Ming Dynasty's "Making Official Ming Dynasty", and Qing Dynasty's "Engineering Practice Rules of Ministry of Works". The other is a set of habitual methods created by craftsmen everywhere according to their own experience, such as the Book of Wood. Among them, the "modular system" detailed in the Song Dynasty's "Constructive Formula" with "material" as its ancestor has played a great role, making the structure and components of Chinese architecture develop along a standardized road [1-3].

"Creating French Style" is an official norm book of architectural design and Construction issued by the Northern Song Dynasty. It is the most complete special book of Architectural Technology in Chinese ancient books. It comprehensively and accurately reflects the scientific and technological level and management experience of the whole construction industry in China from the end of the 11th century to the beginning of the 12th century. It not only shows people the technology, science and artistic style of architecture in the Northern Song Dynasty, but also reflects the social relations of production, the labor combination of construction industry, the level of productivity and other aspects of the situation at that time. "Building Form" is the first detailed record of the ancient modular system (the specific size ratio of various components), but also the first record of ancient architectural patterns, high scientific value. There are five main parts in the Creation Form, namely, explanations of names, systems, limitations, examples and drawings, totaling 34 volumes [4].

3. Parametric Modeling Method of Ancient Architecture

Three-dimensional Modeling Process: Solid Geometry Construction (CSG) is a widely used representation in geometric modeling. The basic idea of building CSG tree is that any complex shape can be represented by adding or subtracting combinations of several simple shapes, or that any complex shape can be obtained by regular set operation between simple shapes. Here, a simple form is called a voxel. Common styling voxels are cuboids, cylinders, spheres, cones, rings, wedges, pyramids and so on. The shape generated by scanning method can also be used as styling voxels. The basic regular operations mainly include * (regular union)* (regular intersection)* (regular difference). Since cuboids, cylinders, spheres, cones, rings, wedges, pyramids and other basic voxels can be generated by scanning method, CSG construction theory can also be expressed as follows: any complex body can be obtained by regular set operation between the bodies generated by scanning method. On the other hand, by studying the structure of CSG tree, we find that the representation process of CSG tree is actually the process of modeling.

Modeling process of oak bucket: The oak bucket is the most common structure in ancient buildings, which must be modeled in three-dimensional modeling. Specifically, the bucket modeling is divided into nine steps (see Figure 1). According to the content of the figure, we build the CSG tree of the bucket. Through decomposition, in order to realize the parametric modeling of oak bucket, we must parameterize the basic voxels of oak bucket. According to the previous theory, we first parameterized the basic voxels of the entity, that is, parameterized modeling of the fruiting entities generated by scanning method [6-7]. According to the theoretical scanning method, there are six main methods to produce fruiting bodies:

- (1) Extrude
- (2) Revolve scanning
- (3) Sweep

- (4) Blend scan
- (5) Wall thickness scanning (thin)
- (6) Advanced Scanning

Obviously, all scanning methods involve the representation of a cross section, and the biggest feature of the cross section is represented by a closed polysemous line.

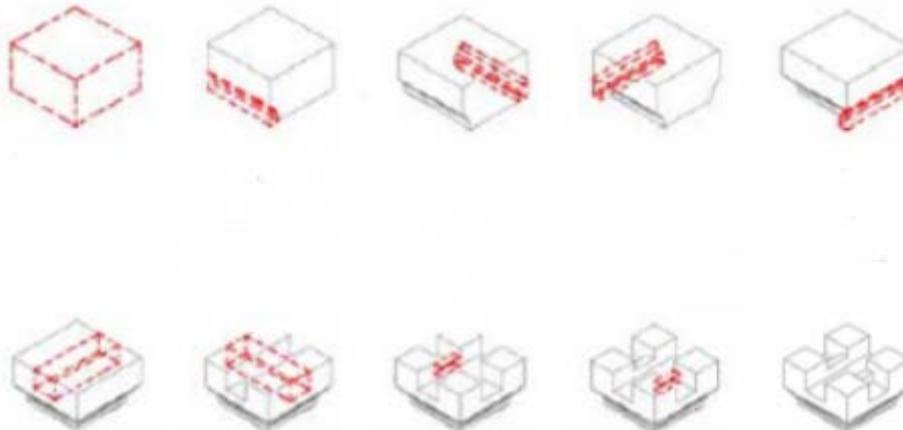


Figure1 Modeling process of oak bucket

3-D Graphic Transform: Graphic transformation is one of the basic contents of computer graphics. It makes the three-dimensional world more vivid. The rotation, translation and scaling of objects all depend on graphic transformation. Graphic transformation is also one of the most basic contents in CAD system. Change can be divided into three steps, as shown below.

(1) Homogeneous coordinates

Definition: The so-called homogeneous coordinate representation is to use $n+1$ -dimensional vector to represent an n -dimensional vector. The position coordinates of the points in n -dimensional space are expressed by non-homogeneous coordinates, which have n coordinate components (x_1, x_2, \dots, x_n), and it's unique. If expressed in homogeneous coordinates, the vector has $n + 1$ coordinate components ($hx_1, hx_2, \dots, Hx_n, h$), and not unique. Obviously, the relationship between "physical" coordinates and homogeneous coordinates is one-to-many. There are two main advantages of "physical" coordinates: it provides an effective method to transform a point set in two-dimensional, three-dimensional or even high-dimensional space from one coordinate system to another by matrix operation, and it is also convenient to use transformation matrix to realize the transformation of graphics; Represents an infinite point. In $n+1$ -dimensional space, the homogeneous coordinates when $h=0$ actually represent an infinite point of n -dimensional [8].

(2) Transform Matrix

The point $P(x, y, z)$ in three-dimensional space is expressed by homogeneous coordinates as $(x, y, z, 1)$. The coordinates transformed are $(x^*, y^*, z^*, 1)$. The corresponding transformation matrix is 4×4 square matrix T . T is divided into four sub-arrays, the upper-left 3×3 sub-arrays generate proportion, reflection, staggered and rotation parts; the lower-left 1×3 sub-arrays generate translation transformation; the upper-right 3×1 sub-arrays generate perspective transformation; and the lower-right 1×1 sub-arrays generate overall proportional transformation. Complex transformations are composed of basic transformations. Since matrix multiplication does not satisfy the commutation law, the order of transformation matrices can not be arbitrarily reversed. Special attention should be paid to the order of transformation [9].

(3) Parametric Description of Transform Matrix

Combined with the research of ancient building model and three-dimensional modeling for many years, in the process of parameterization of ancient buildings, three basic transformations are mainly used: translation transformation T_t , rotation transformation T_r , symmetry transformation T_m and so on. Therefore, for each basic transformation, the corresponding parameter variables are defined to describe it, so that the whole transformation matrix can be formed. The order of the transformation matrix should also be paid attention to. Of course, the corresponding transformation

matrix can also be given directly, but it is more complex. Combined with our research on three-dimensional modeling experience, it is relatively easy to give the corresponding description of various transformations in modeling, and then the corresponding transformation matrix can be automatically generated by the system.

Case Modeling: Virtual Simulation Technology:Case 1 In the three-dimensional digital modeling of carved decoration of Hakka ancient buildings, in view of the carved decoration of doors and windows, we should first understand its classification and characteristics, that is, the art of doors and windows occupies a very important part of the ancient buildings. The carved decoration of doors and windows of Hakka ancient buildings can be seen almost everywhere, as shown in Figure 1. Before glass was used in the windows of ancient buildings, it was necessary to use more intensive panes in consideration of the design requirements of wind and rain shielding. The style of window pane has been developing and innovating in the long history of thousands of years. It conforms to the aesthetics of human beings in a specific period. The design of window carving has been brought into many elements of life. Figures 2 and 3 are illustrations of decorative carvings of doors and windows. In the process of modeling, because the decoration of doors and windows is irregular graphics, spline lines are used to describe the contour on the one hand, on the other hand, after drawing two-dimensional plane model, it is necessary to construct structural lines to determine the direction and turning point of the whole model, such as the stretching posture of flower petals, in order to facilitate the construction of three-dimensional effect later. In order to enhance the stereo effect of the three-dimensional model, it is necessary to use the tangent tool to construct the ribs to emphasize the turning point.



Figure 2 Examples of decorative carvings of doors and windows(geometric image class)



Figure 3 Examples of decorative carvings of doors and windows(Four Treasures of the Study)

Case 2: In the three-dimensional digital modeling of the famous ancient building "Palace Museum", for the surface structure of the Palace Museum, it is necessary to use three-dimensional scanning technology to obtain graphical data first, then integrate scene data, so as to distinguish the data categories, and finally to make the model of the structural components of the ancient building, that is, the structural components of the ancient building. Model making includes geometric model making and texture mapping. Geometric model making refers to the model making without texture mapping such as bench base, brick wall, doors and windows, column beam, bucket arch, tiled ridge animal, etc. Texture mapping refers to the texture mapping of building surface completed by repair, stitching and processing in three-dimensional software, referring to the reference photos recorded on the spot, using the texture mapping in three-dimensional software, and giving function. The plain geometric model is given to restore the true shape and color of the part. We should pay attention to the fact that the three-dimensional model making of ancient buildings is the same as the actual construction of ancient buildings. The best way is to make the three-dimensional model of ancient buildings from the foundation to the wall structure and then to the roof in this order. Therefore, it is very important to control the time schedule of the single model making in the whole three-dimensional model making of ancient buildings. Fig. 4 and 5 virtual simulation models of the Palace Museum. Fig. 6 is the physical picture of the Palace Museum.



Figure 4 Virtual simulation model of the Palace Museum(a)



Figure 5 Virtual simulation model of the Palace Museum(b)



Figure 6 Physical picture of the Palace Museum

The comparison shows that through the three-dimensional modeling technology and virtual simulation technology, the Forbidden City can be highly restored to provide help for the work.

4. Conclusion

In this paper, through the analysis of the modeling process of three-dimensional model of ancient buildings, the general methods of three-dimensional modeling of ancient buildings are summarized. Combining with the parametric method based on the construction process and taking Dougong as the representative, the parametric modeling technology and virtual simulation technology of ancient building models are systematically put forward. In this paper, by studying the general modeling methods of ancient buildings and developing general modeling components, we have made an exploratory study on the general digital modeling methods of ancient buildings in China, so as to realize the systematization of digital modeling of ancient buildings and sharing of model data; explore the modeling methods of carving decoration of Hakka ancient buildings, and confirm the method. It can complement and enrich other three-dimensional modeling software which is inconvenient to create fine models, realize the integration of building models and fine building

components; explore the application of three-dimensional digital modeling and virtual simulation technology of the Palace Museum, the results show that as far as the three-dimensional digital modeling technology of ancient buildings is concerned, the technology is in the cultural heritage. There are many research and practice activities in the field, and the application of this technology is very successful. At the same time, with the virtual simulation technology, the matching degree between the color and texture of three-dimensional model and the actual color and texture can be managed to achieve a high degree of restoration.

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References

- [1] Plessis A D,Slabbert R,Swanepoel L C,et al.Three-dimensional model of an ancient Egyptian falcon mummy skeleton[J].Rapid Prototyping Journal,2015,21(4):368.
- [2] Lei H,Huang H,Chen C,et al.Three-dimensional Modeling of Hakka Earth Buildings based on the Laser Scanned Point Cloud Data[J].Remote Sensing Technology&Application,2015,82(5):2007-2016.
- [3] Simioni E,Ratti F,Calliari I,et al. Three-dimensional modeling using x-ray shape-from-silhouette[J].Applied Optics,2011,50(19):3282.
- [4] Gill A A.Digitizing the Past: Charting New Courses in the Modeling of Virtual Landscapes [J]. Visual Resources, 2009, 25(4):313-332.
- [5] Wang S,Fang L,Chen C,et al.A Single View Type 3D Reconstructive Method for Architecture Based on Structured Scene[J].Journal of Geo-Information Science,2016,18(8):1022-1029.
- [6] Risha U A A.Radiocarbon dating and the 36 Cl/Cl evolution of three Great Artesian Basin wells at Dalhousie, South Australia[J].Hydrogeology Journal,2016,24(4):1-14.
- [7] Liu W L,Zhao X P,Wang X L,et al.Based on Three-Dimensional Modeling of Laser Scanning Technology in Antiquities[J].Applied Mechanics&Materials,2013,256-259:2315-2319.
- [8] Ritchie B D,Hardy S,Gawthorpe R L. Three-dimensional numerical modeling of coarse-grained clastic deposition in sedimentary basins[J].Journal of Geophysical Research Solid Earth, 1999, 104(B8):17759-17780.
- [9] GOUW, Marc J P. Alluvial architecture of the Holocene Rhine–Meuse delta (the Netherlands)[J]. Sedimentology, 2010, 55(5):1487-1516.
- [10] Warren J D, Demicco R V, Bartek L R. Fuzzy Predictive Earth Analysis Constrained by Heuristics Applied to Stratigraphic Modeling [J]. Studies in Fuzziness & Soft Computing, 2007, 215:381-430.