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3D Modeling and Digital Preservation of Ancient Architectures Based on AutoCAD and 3DMAX

Chenxi Tian[1]

[1]Department of Art Design, Zhengzhou Institute of Technology, Zhengzhou, China

Corresponding author: Chenxi Tian, haoxixi100@126.com

Abstract. The Chinese civilization has a long tradition and has a rich ancient architectural culture. During the long years, the ancient sages created splendid architectural complexes, such as: Forbidden City, Summer Palace, Great Wall and so on. However, with the passing of time and the changing of years, many precious ancient buildings were destroyed because of human activities. In recent years, with the development of digital technology, this new type of technology has provided an effective means for the protection and restoration of ancient buildings. This paper uses AutoCAD and 3DMAX to carry out three-dimensional modeling of ancient architectures and realizes the digital preservation of precious architectural relics.

Keywords: 3D Modeling, Digital Preservation, Ancient Architectures, AutoCAD, 3DMAX.
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1 INTRODUCTION

Buildings with national features are valuable cultural treasures left by our ancestors. National architectures have important values in culture, history, art and many other aspects. A well-preserved national architecture is not only an important piece of historical and cultural information at the time of its construction, but also a historical witness of social progress and historical and cultural changes, relevant results proposed by Sholts et al. [1, 2]. National architecture is non-renewable, once it is destroyed, it'll be a regret that we have no way to reverse the facts. Like natural disasters such as floods and fires, however, they are inevitable. In fact, in our lives, there are still a lot of non-natural disasters, and they are destroying our architectural heritages silently.

For example, Lingguan Building is located in Jiulong Town, Mianzhu City, Sichuan Province. It was built in the Ming Dynasty Chongzhen Period, and it was built by the prime minister Liu Yuliang to commemorate Wang Lingguan, the God of Heaven. The building covers an area of more than 20 acres and is composed of seven grand golden palaces. Chinese traditional mortise and tenon structure is adopted. The building is 16 stories tall, and it is known as the tallest wooden tower in Asia. For hundreds of years, the tower is prosperous, incenses are burning all the time. At noon on December 10, 2017, at the Lingguan Building of the Jiulong Temple in Jiulong Town, Mianzhu City, Sichuan Province, a large fire broke out in the main hall and ignited the Lingguan Building, which now completely burnt down and the architecture cultural heritage has been

destroyed on that day. This is deeply painful. The comparison of the building before and after the fire is shown in Figure 1.

Digitization is to transform a lot of diversified information into digital data and store it into the database, and then build a digital model by data and figures in the database. Digitization technology is a kind of technology that displays, processes and transmits all informatized information through computers, optical fibers, communication satellites and other information devices, relevant results proposed by Colin et al. [3, 4]. Deng et al. introduced that Virtual reality (VR) technology can use different modern technology software to save information, for example, AutoCAD, 3DMAX and other VR design software can conduct 3D modeling [5, 6]. This digitization preservation method has a great promoting effect in the protection and preservation of ethnic buildings and national cultural heritages.

Figure 1: Before and after burning comparison chart of Ling Guan Lou.

2 MODELING METHODS AND STEPS FOR AUTO CAD AND 3DMAX

When combining Auto CAD with 3D MAX to construct models of buildings, its steps include: field data acquisition, which can be either a total station digitization-mapping or an RTK mapping; then the collected data can be imported into software, then use the function in the software to create the model; second, texture collection, processing, and posting; at last, output the whole established model. The process is shown in Figure 2.

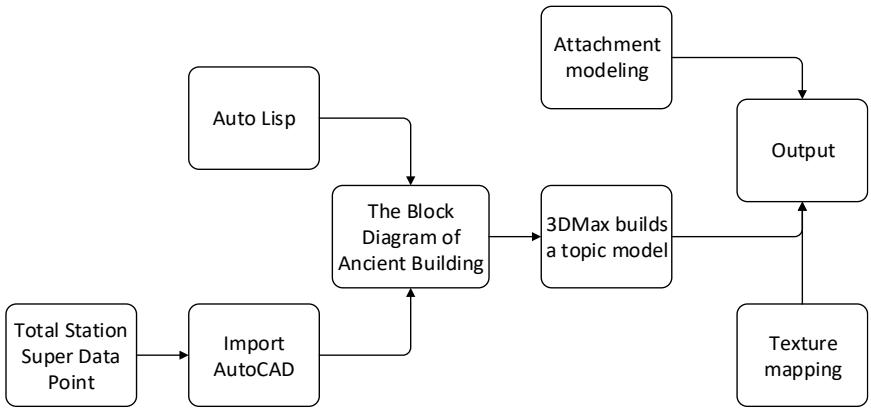

Figure 2: Modeling process based on AutoCAD and 3DMAX.

2.1 Building Wireframe Generation

Field observation points measured by the field need to be imported into the internal processing software. Currently, the most commonly used mapping software is Auto CAD. The field coordinate data in the total station is displayed in Auto CAD, and specific graphics are required. The program generally requires the operator to display the wild spots in advance, and write them into the Auto Lisp program through the automatic connection code, and automatically recognize the field code to draw the building line drawing by using the program running loading method. Field coding can be composed of 4-bit codes, which are mainly divided into category codes and relationship codes. The category code is designed according to a certain law. The relationship code (also known as the connection relationship code) is also designed with 2 digits. The first digit uses the English initials to indicate the position of the representative point. For example, B represents the starting point, M represents the intermediate point, E represents the ending point, and C represents the closing point. The latter digit is used to indicate the connection line shape. For example, "1" means connecting with a straight line, "2" means connecting with an arc, and "3" means connecting with a spline. The observation of the feature points of the structure must be carried out in accordance with the prescribed coding rules.

When some of the basic feature points of the measurement process are blocked and cannot be observed, it is necessary to use Geometry to obtain a closed structure in Auto CAD. Then the bus block diagram is analyzed in Auto CAD, and a series of analysis and processing are performed on the 3D model, including anatomy and deletion of annotations.

2.2 Establishment of 3D Model

Before importing the model into 3DMax, first we set the unit of 3DMax so that its system unit ratio is the same as the display unit ratio, and it is set to millimeter. Then we import the modified wireframe in AutoCAD. DWG file is imported into 3DMax to select the original AutoCAD file, select the level to be imported into 3DMax in the "Layer" option.

After importing 3DMax, the graphics generally have a certain angle of intersection with the view. In this case, you need to reorganize all the graphics and rotate them to the appropriate position (such as parallel to the view) so that the wireframe can be edited and modeled well in any of the three views, then use a series of operations such as drawing lines and rectangles to stretch the appropriate length using the extrusion function. Some unmeasured internal details, such as doors and windows, decorations, etc., are modeled according to the resulting size and photos taken on site, and the built attachments are incorporated into the model of the main building.

3D modeling is different from mapping of flat graphics. It is not possible to simply use the connection of measured points and make some additions or modifications to complete the modeling. For example, for point data collection on the main wall of a building, the line connecting the measured points at the base of the wall should be a long and narrow rectangle on the same elevation. The results obtained are not strictly rectangular, and they are not on the same elevation surface. The model built is naturally not on the same elevation surface. Then, when modeling, you need to open the 2.5-dimensional capture in 3DMax, so that the model can be built on the same plane, and then moved to the real position of the model in the top view or other view.

2.3 Texture Mapping

A texture map is a process that uses images, functions, or other data sources to change the appearance of a surface at every location. For example, instead of using a precise geometry to represent a brick or wooden floor, it just attaches a brick or wooden floor image to a polygon. This saves a lot of styling work, saves memory, and speeds up drawing. For the texture of the building model, it is usually necessary to take photos with a digital camera on site, change the material, paste the modified image onto the shader and assign it to the building, and then apply the texture coordinates.

3 A MODELING PROCESS OF ANCIENT ARCHITECTURE

Because some structures of ancient buildings have irregularities and complexities such as eaves and spires with sharp edges, the NURBS surface model is not suitable for representing the external 3D models of ancient buildings [7, 8], because NURBS surfaces mainly form complex surfaces by fitting the contour lines of objects, it is suitable for industrial equipment and sculptures with streamline-type or smooth-type surfaces . The Triangular Irregular Network (TIN) model can accurately represent the shape of a complex object to reduce the loss of model accuracy and maintain its original features.

3.1 Model Geometry Cleaning and Repair

Edge repairing: After the TIN model is built, some voids would appear on the surface of the model, and YIN model cannot be constructed in these areas. The repair of these loopholes needs to be fixed according to the type of loopholes, in 3DMAX software there are three interpolation methods: curvature-based, plane-based and tangent-based. For the shape of loopholes, there are three types: full filling, partial filling and bridging [9]. When repairing the loopholes, reasonable repair methods should be used for those complicated voids. For loopholes with noisy data, the noisy data should be deleted first and then repaired. When repairing the loopholes, manual methods are adopted mainly, therefore, the efficiency is low and the workload is large. Figure 3 shows the effect before and after the loophole repairing.

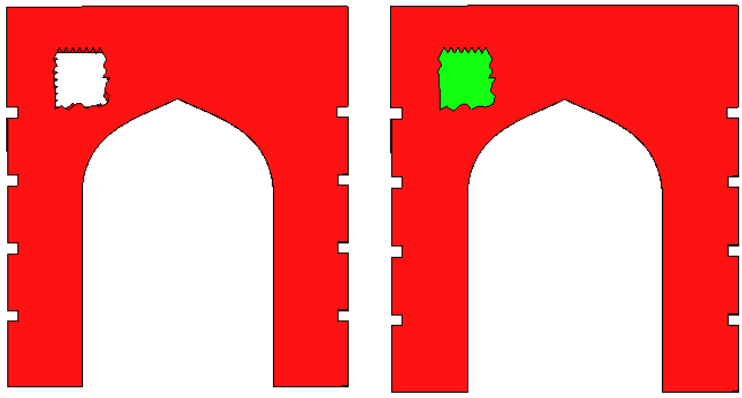

Figure 3: Comparison of effect charts before and after the model is repaired.

3.2 Model Simplification

Since a large amount of point cloud data is collected during the scanning of the three-dimensional laser scanner, after the data preprocessing, the data amount is still large, therefore, when constructing the TIN model, the generation of redundant data is inevitable. For example, a plane can be constructed by only two triangles, however, due to the high density of point cloud data, it is possible to have multiple triangles in the same plane. In addition, the more the TIN, the slower the running speed is when using computers for processing, therefore, under the condition of maintaining model characteristics, the number of TIN can be simplified properly [10]. In the 3DMAX software, the model simplification uses the curvature priority option. In the simplification process, the curvature priority method maintains more triangles where the curvature is higher, and maintains fewer triangles when the curvature is lower, this means maintains the original features and shapes of the model. Table 1 shows the experimental results of the simplification with different spacing accuracies, Figure 4 shows the effects of simplification at different intervals.

Point interval(m)	Triangle network number	Proportion

0.01(Initial value)	1533364	100.0%
0.02	1453681	94.8%
0.03	1041454	67.9%
0.04	988584	64.5%
0.05	685484	44.7%
0.06	517468	33.7%
0.07	487521	31.8%
0.08	201843	13.2%
0.09	145625	9.5%

Table 1: Simplified test results with different pitch accuracy.

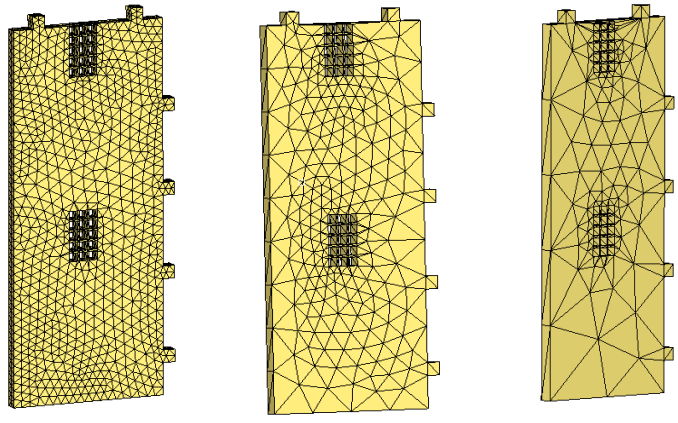

Figure 4: Simplified renderings at different intervals（a）0.02（93.6%）Window diagram (b)0.06(37.6) Window diagram （c）0.09(9.9%) Window diagram.

3.3 Triangular Model Construction

The 3D modeling in this section mainly adopts a geometric modeling method, which uses the extraction of building feature points and feature lines to obtain the pavilion's plan, elevation, profile, and the 3D dimensions of some important parts. Import these 2D line graphs into 3DMAX, and then adopt 3DMAX software to model the pavilion's regular parts such as steps, platforms, pillars, eaves and square pillars using linear regression piecewise linear fitting and other method. For irregular parts such as brackets, plinth, vertical ridges, and crown roof, we can extract the surface feature points and feature lines first, and then use rotating, lofting, stretching and other methods for modeling. For those parts that are difficult to construct by the above methods, the TIN model can be used for modeling [11].

The TIN model can better represent the shape and features of the crown roof in details [12]. For the components used in the construction of TIN model, they can also be imported into 3ds Max, unify the units with previous established model and conduct matching and combining, after all parts are built up, eventually it forms a complete 3D TIN model of the pavilion, as shown in Figure 5.

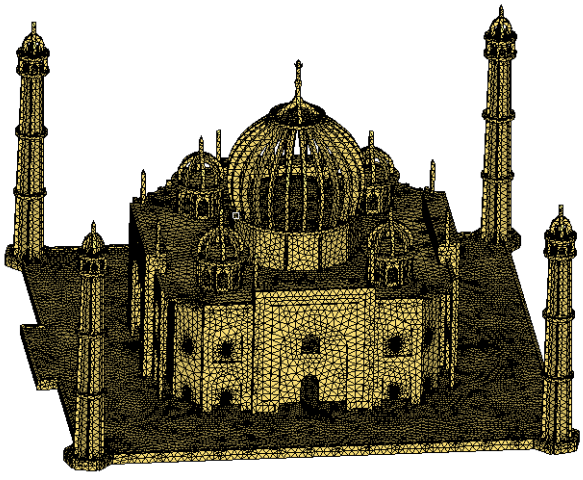

Figure 5: The complete triangulation model of ancient architecture.

3.4 3D Model Texture Reconstruction Rendering

3DMAX can map the established TIN model, it can also map the established geometric solid model. In 3DMAX, this paper uses the UV mapping method to perform texture mapping on the 3D model of ancient architectures [13]. Use the created 3D model and the processed texture photos to create different material spheres in 3DMAX, and select appropriate diffuse reflection values, opacity, irregularity parameters and tile times for the mapping types according to different materials, and then assign to different building components [14]. In the mapping process, for the surface components, we must choose a good mapping method, so that the best mapping effect can be achieved. Figure 6 shows the 3D model after texture mapping.

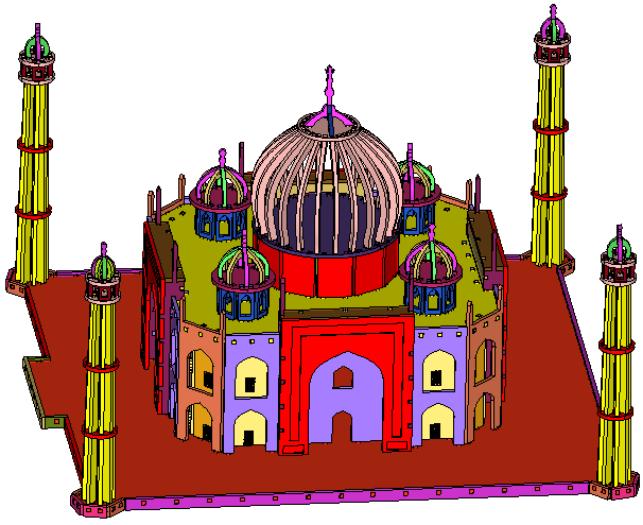

Figure 6: After rendering of the three-dimensional model of ancient architecture.

3.5 Parameterized Reconstruction of Ancient Architectural Engineering Structural Models

Because the ancient construction techniques are very different from the modern ones, and the ancient buildings are old, the drawings and drawings that can be borrowed are scarce. Usually the relevant personnel are involved in the mapping of ancient buildings. The data collected by this traditional method is usually represented by the plane, elevation and section drawings of ancient buildings. It is only the plane lines and related text descriptions, which cannot be intuitive. If the results of the surveying are based on the input building type, the bucket modulus, the type of the base, the structure, the roof form, etc., on the basis of explaining the semantics of the ancient architectural engineering, the three-dimensional model is assembled, so that the information of the ancient building surveying and mapping is included. In the three-dimensional model, the digital three-dimensional model contains more information than the two-dimensional graphics, and is closer to people's daily life space. It can accurately, image, and richly record the appearance of the building, architectural style, internal structure, etc. The archival record, repair and reconstruction and reconstruction work provide new technical means.

The rapid reconstruction of the 3D engineering model of the ancient building is completed hierarchically. The main steps of reconstruction are shown in Figure 7.

The 3D model based on the ancient construction surveying and mapping engineering drawings contains all the engineering dimensions and structural relationships of the ancient buildings. You can inquire the dimensions of each part at any time, and zoom in to view the details of each part. You can also view and view through layer management according to your needs. You can also set the viewpoint to observe from different orientations and heights. For the complex combination parts and structural relationships, the three-dimensional model is used to represent the image and is intuitive, which provides a new technical means for the reconstruction and restoration of ancient buildings.

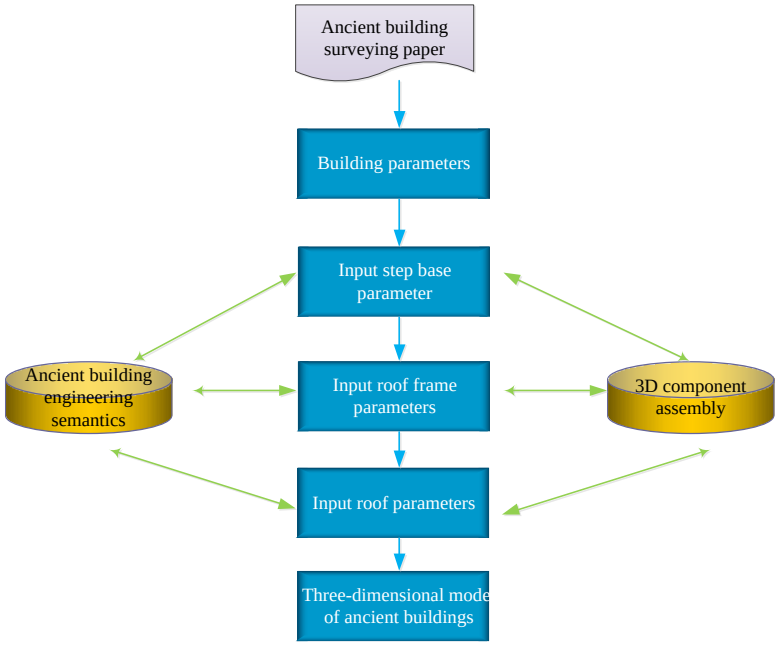

Figure 7: Block diagram of parametric ancient building engineering structure model reconstruction.

4 ANALYSIS OF 3D MODELING ACCURACY

4.1 Digital Building Requirements for Fine Models

1) The degree of fine modeling

To highlight the authenticity of the external environment, 3D modeling must be very detailed, and the requirements for its comprehensive degree are not very high. However, a large amount of terrain data will bring too much pressure to the system, so in the modeling, some places can use textures to express. As usual, modeling is performed when the structure is ≥0.5m. In addition, the fine-grained modeling of the required shape and texture microstructure should be consistent with the field architecture. The fine modeling process flow is shown in Figure 8.

2) High processing

In 3D modeling, the elevation of a building can be calculated. The height of each floor of the building is basically the same, about 3m. After the modeling preparation is completed, the buildings of the same height can be grouped, using the extrusion and stretching functions in 3DMax, the ratio is calculated by dividing the height calculated by Lidar by the height at the time of modeling, and the final model. The height and the physical height can be achieved.

3) Geometric model construction

In the 2D plan, you can use the functions of stretching, extrusion, etc. in 3DMax for simple modeling, and then build the details, such as steps, fine modeling, and texture rendering.

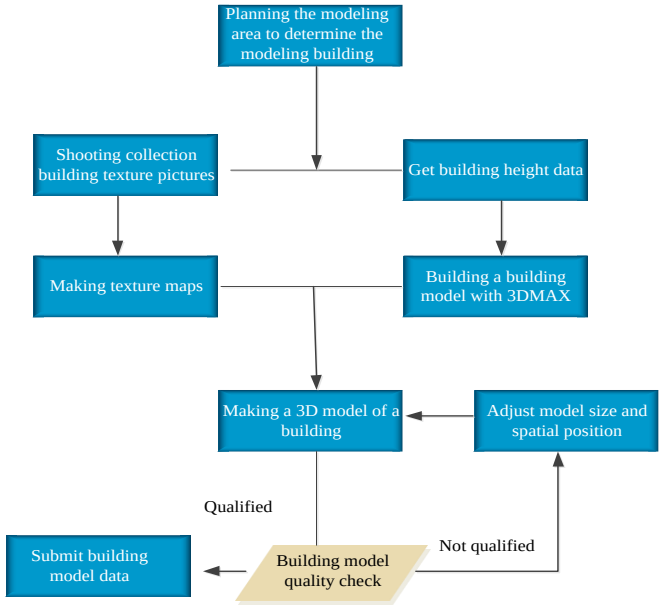

Figure 8: Fine modeling process.

4.2 Accuracy Analysis of AutoCAD Data

The accuracy of CAD mapping is a critical factor in the accuracy of 3DMax modeling when preparing data. The following two methods of mapping are introduced to control the accuracy of CAD and improve the accuracy of 3D modeling. Map digitization is the main way to provide basic spatial data for GIS. It is also the main method for producing digital maps at present. Its quality is

directly related to the efficiency of GIS and the use value of digital maps. The two key indicators for evaluating the quality of digital maps are its geometric accuracy and mathematical precision, which directly represent the plane position accuracy of the base map. The accuracy of these digital maps depends on the original accuracy of field data collection. According to the way of data collection, the source of the error is different. At present, there are several methods for data collection for digital maps, such as digital ground mapping, topographic map digitization, and aerial photogrammetry. The accuracy of ground digital mapping is related to instrument accuracy, observation accuracy, and the level of internal mapping personnel. The digitization of the topographic map is related to the original accuracy of the paper topographic map and the accuracy of the digitizer and the accuracy of the digitization in the field. Aerial photogrammetry is related to the location of aerial photographs and the accuracy of analytical software.

1) Original base map accuracy

Copying the original image can be expanded or reduced. If the existing map is used for digitization, the original image should be copied into a large or reduced copy, so the map data is available. The quality depends on the accuracy of the original image, the error generated during the original copying process, and the error caused by the long-term deformation of the map data.

2) Design method and accuracy of computational model in software system

When the software is compiled, the mathematical model used is different, and the final precision is different, which will directly affect the accuracy of the map digitization. Therefore, you must choose a software that is comprehensive in function, high in digital accuracy.

3) Digital process error

The error generated when digitizing the base image comes from many aspects: firstly, it has a great relationship with the individual level of the operator. The attitude is correct and the skill is skilled. The digitization of the base map is higher, and vice versa. Secondly, it has a great relationship with the sharpness of the original image. The clearer the original image, the higher the accuracy after digitization. Finally, it has a lot to do with the complexity and density of the original image.

4) Accuracy of the output device

The accuracy of the vector plotter output is determined by the ability of the stylus to control the motor. In the drawing, the step size should not exceed 0.054 mm. At present, the low-resolution inkjet plotter can reach 3-5 points per millimeter. The instrument is not only affordable, but also easy to purchase, and the quality of the produced products is also good. The error of the production profile of the working plotter is generally less than 0.2 mm.

4.3 Accuracy Analysis of Buildings During the Modeling Phase

In 3D modeling, close-up photogrammetry is often used to collect building heights. Photogrammetry methods have evolved into an efficient and reliable precision measurement method for a wider range of applications in building height measurement. Compared to other measurement jobs, the height of the building used for 3D modeling is not high enough and does not require much repetitive observations. With the close-range photography method, in addition to its advantages of observing non-contact, the accuracy of photography points is also significantly improved, and the application of a wide range of computers enables people to adopt strict methods to deal with analog digital photography system errors.

The height of the ground objects obtained by photogrammetry was used for three-dimensional modeling, and some buildings were inspected in the field. The inspection data is shown in Table 2. The measurement of the height of the feature by the photogrammetric means is consistent with the theoretical value.

Ancient building	Measurements (m)	Calculated value (m)	Absolute error (m)	Relative error (m)

JING1	51.7	51.11	0.49	0.95
JING2	18.5	17.45	1.01	5.56
JING3	17.9	18.76	0.86	4.91
JING4	17.9	17.36	0.43	2.47
JING5	17.9	17.37	0.43	2.47
JING6	52.5	51.87	0.82	1.59
JING7	52.7	50.76	1.81	3.43
JING8	46	45.69	0.75	1.67
JING9	45.2	46.09	0.72	1.60
JING10	62.9	63.08	0.71	1.12

Table 2: Photogrammetric building height accuracy analysis.

5 CONCLUSION

Ancient architectures, as important human historical and cultural heritages, their protection work is much valued both at home and abroad. In recent years, with the development of computer technology, various digital protection technologies have emerged one after another. This paper studies the modeling of ancient architectures based on AutoCAD and 3DMAX software, sorts the modeling process and post-processing methods of different TIN models, and achieves the digital preservation of precious architectural relics.

Chenxi Tian, https://orcid.org/0000-0002-7375-8221

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