Research on 3D Reality-based Modeling and 3D Virtual Walkthrough for Cultural Archaeological Sites.

A Case Study of the Small Wild Goose Pagoda in the Tang Dynasty

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Abstract

Taking the Small Wild Goose Pagoda in Tang-Dynasty as a case, study this paper mainly researches the key technologies of the 3D reality-based modeling from real data and of the 3D virtual walkthrough of the cultural archaeological sites. Firstly, this paper puts forward the method of the 3D digital data process of the cultural archaeological sites by way of combining the technologies of the 3D laser scanning of the large scenes and the digital photography, which enables the prompt and accurate digital data acquisition without damaging the cultural archaeological sites; then based on the laser-synchronized visual image of the ancient buildings, the paper proposes the method of 3D reality-based modeling from real data with the adoption of local texture mapping; finally, the paper introduces the systematic architecture, technology roadmap and all the key technologies of a 3D virtual walk-through system based on WebGIS for cultural archaeological sites.

The implementation of the methods proposed in the paper cannot only create a reality-based 3D digital modeling of the Small Wild Goose Pagoda, which helps to realize the digital protection of this important cultural site built in 707 AD, but also create a digital object with the 3D virtual walkthrough function for the Small Wild Goose Pagoda so that people can enjoy its unique historical, cultural and tourist values based on the Internet.

Key words*: digital archaeological, 3D Reality-based modeling, virtual walkthrough*

1 Introduction

It is known to all that cultural archaeological sites are the very important material data in research of the ancient history, culture, art and the development of science and technology. However, with the passage of time, these ancient historical and cultural sites have been suffering considerable damages, which makes the digital protection of these sites in urgent need. In addition, the reality-based digital technologies are as well in great need to fully display the historical charms of these sites and improve their cultural and tourist values.

Evidently, the reconstruction of the cultural heritage sites is an exciting field of application. Therefore, how to realize the accurate 3D data measure without damaging the ruins of ancient buildings and relics, how to create the 3D reality-based modeling from real data, and how to realize the 3D internet-based virtual walkthrough would be a worthwhile subject[1].

Taking the Small Wild Goose Pagoda in Tang Dynasty as the case, this paper focuses on the following two aspects: engineering application of the 3D scenes modeling based on laser scanning and the design and implementation of the 3D scenes virtual walkthrough system. Then, the research is expected to be an example and reference for the digital protection of other cultural archaeological sites.

1.1 The research object

The Small Wild Goose Pagoda built between 707～709A.D. is one of the two significant

[1] Barche Barcelo J., Forte M., and Sanders D.H., *Virtual Reality in Archaeology* (Oxford: Archeo Press, 2000).

pagodas in the city of Xi'an, which is the site of the Tang-Dynasty capital Chang'an. The pagoda has a brick frame built around a hollow interior, and its square base and shape reflect the building style of other pagodas in the era, as shown in figure 1.

Figure 1. The Small Wild Goose Pagoda Scenes

1.2 The technical roadmap

Basing on the practice, we draw the corresponding technical roadmap, as shown in figure 2.

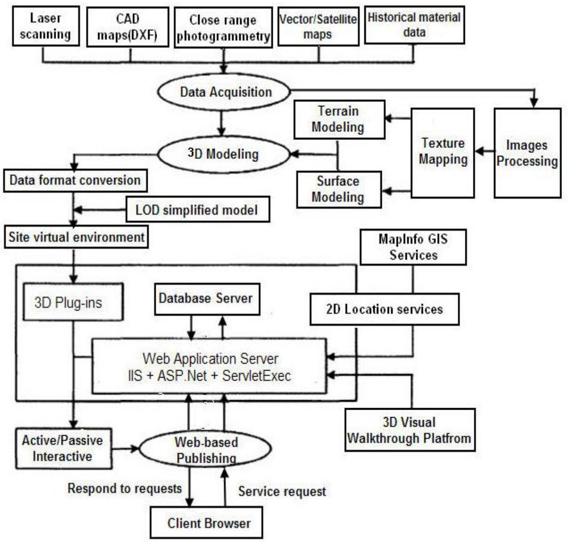


Figure 2. The technical roadmap

In our view, the seven steps should be involved in the project, as described bellow.

Step1. *Data Acquation*, which concretely includes getting the 3D geometric data and the 3D texture data of the cultural sites.

Step2. *3D Modeling*, which is to create the surface models and the terrain models of cultural sites.

Step3. *Texture Mapping*, which is to create the texture and do the texture mapping.

Step4. *Models Optimizing*, which is to simplify and reconstruct the triangle models for getting better performances.

Step5. O*bjects Creating*, which is to assemble the surface models and the terrain models to enrich the visual effects of the geographical environment.

Step6. O*bjects Embedding*, which is to embed the site models with 3D virtual walkthrough function in the CAWS^{3D} developed by our team;

Step7.*Web-based Releasing*, which is to realeaze the objects of the cultural sites on the Internet.

2 The technical method and process

2.1. Data acquisition

2.1.1. The 3D laser scanning model

Precise mapping work is required in order to provide the first-hand material for the ancient architecture protection and to provide important data for research on the cultural sites. At the same time, after thousands of years, the ancient buildings of the cultural sites have mostly suffered serious deformation and damages due to natural factors such as wind, rain, lightning strike, earthquakes, etc.. The traditional manual measure methods are in low measurement precision, in addition, researchers need to climb the ancient buildings, which may tend to destroy the buildings, relics and antiques etc. In contrast, through laser 3D scanning technology, the 3D model of static object of the cultural heritage sites can be acquired fast, precisely and multi-directionally, and the model can be analyzed and proceed further[2].

It should be noted that although the 3D laser scanner can obtain the high-density surface space coordinates information of the sites scenes, but the high-precision color texture information for realistic modeling is still missing. Therefore, it is necessary to obtain the high-precision colorful texture information with the adoption of the high-precision digital cameras while scanning the cultural heritage sites. we called this method "*a fusion of laser measurement technology*".

[2] Ming YU, et al, "Reaearch on mapping of ancient architecture based on laser three-dimension scanning technology," *Science of Surveying and Mapping*, 2004, 29(5): 69–71.

The operating mode is described as follows: during the scanning process, the point cloud data of the sites scenes are obtained by the laser scanners, and the colorful texture information of the site scenes is obtained by the coaxial digital cameras. After post-processing, the realistic 3D model is constructed, as shown in figure 3.

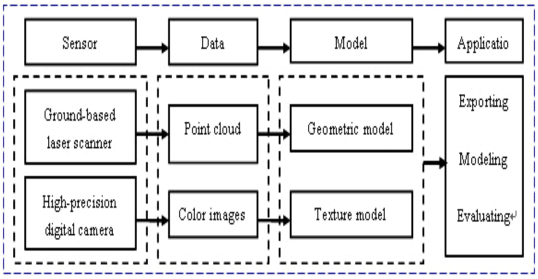


Figure 3. The fusion 3D laser scanning model

2.1.2. The 3D scanning plan

The Small Goose Pagoda site contains many ancient buildings from the Tang Dynasty to the Qing Dynasty, as well as many modern buildings, so the resrach team divide the site scenes into two regions: the ancient buildings with the Pagoda body as the center and the modern bulidings with the modern exhibition room as the center. Then we determine the scanning strategy of "ancient buildings with high-accuracy scanning and the outbuildings with middle-accuracy scanning", and place four close-range scan-stations in the four directions of the pagoda boby facades, four far-range scan-stations in the four directions of the pagoda ridges, as shown in figure 4.

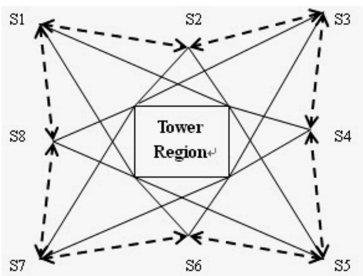


Figure.4. Scan-station map of the pagoda

In addition, a set of measurement targets are set in the key geometrical locations of the pagoda body like the top, the middle and the base. Of the measurement targets, at least three where the adjacent scan-stations locate are not on the same line.

The moving path of the laser scanner adopts the "Foresight to Backsight" method. During the scanning process, the serial numbers and the pre-planned path should be strictly carried out, which is benefical to the management of the sub-point cloud data of the view, but also helpful to simplify the registration of the multiple point cloud data.

2.2. The 3D registering method

The accuracy is the key problem in the multiple point cloud registration. As we know, accuracy errors result from two choices: (1) how to choose the initial transformation matrix at the beginning of iteration; (2) how to choose the appropriate registration algorithm.

The typical multiple point cloud registration methods are ICP algorithm and feature-based registration methods. ICP algorithm requires overlapping 3D data points from the view, with points as the registration unit. Feature-based registration method requires first the calculation features from the 3D point cloud, and no registration can be obtained without calculation features or with the calculation features insufficient[3].

Generally, the ancient buildings and relics of the cultural sites have very complex geometrical forms and are extremely difficult to calculate their appropriate 3D features. Basing on this situation, we propose a *"step-by-step"* registration strategy, that is, first of all, to carry out the initial iteration using lower-resolution sampling data, and then to increase the data sampling rate in the next round of the iterative process in order to achieve precision of the match from the beginning.The specific process is as follows:

Definition: ***reflectance image*** is formed by the reflectivity values of all the sampling points of each view in 3D scenes, and has all the characteristics of the general image.

Step1. The adjacent reflectance images are divided into M and N sub-images, assuming that the sub-images contain the same number of pixels.

Step2. The similarity between adjacent reflectance images is calculated based on Mahalanobis distance, and the initial coordinate transformation matrix is identified by the sub-image's centroids of the three pairs of the largest similarity.

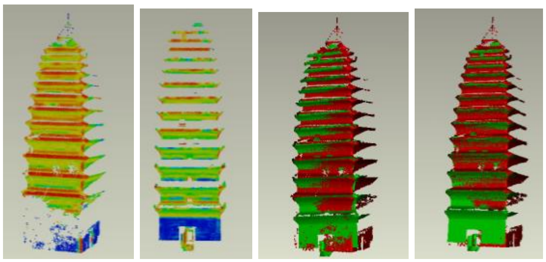
[3] Johnson A.,et al, "Surface registration by matching oriented points" (Proceedings of International Conference on Recent Advances in 3D Digital Imaging and Modeling, Ottawa, 121–128, 1997).

Step3. Based on the initial coordinate transformation matrix, the 3D edge points of the adjacent view are translated to the same coordinate system at first, and all of the 3D edge points are registered by using the improved ICP algorithm, and the transformation matrix is further optimized.

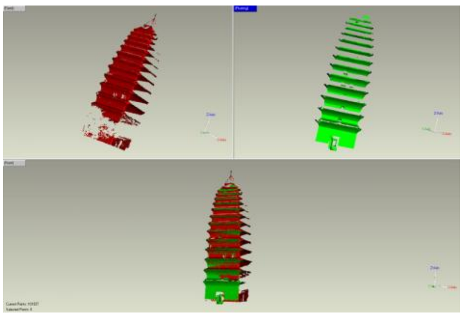
Step4. Based on the optimized transformation matrix, all of the 3D points of the adjacent view are translated to the same coordinate system.

Step5. The results of step 4 will be seen as the registration object of step 5, repeating steps 1 to 4, then all of the local point clouds will be registered finally.

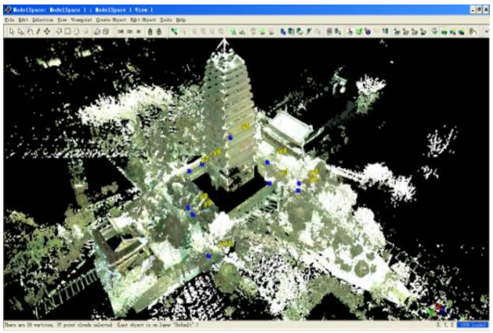
The advantages of the method can increase the registration speed by reducing the amount of iterative calculations, and can obtain more satisfactory registration results. We apply the above method to register the point cloud data of the Small Wild Goose Pagoda, as shown below.



(a) station 1 (b) station 2 (c) stage result (d) final result



(e) Registration process of S1&S2



(f) The sites point cloud

Figure 5. Registering the multiple point cloud by using step-by-step method

In practical applications, in order to avoid convergence slowly or even divergence due to incorrect initial selection, it is advisabale to adopt the human-computer interaction to select some general overlaping points in two point cloud as the initial point of iteration process so that iterative initial value is closer to the true value, thereby speeding up the convergence rate and shortening the computing time.

2.3. 3D segmentaion

2.3.1. The segmentation method

The 3D sites segmentation is a process of extracting the central building from the site point cloud data. Its algorithm can be roughly divided into three categories: to be based on regions, to be based on edges and to be based on the mixture of regions and edges. The first algorithm adopts the point-by-point scanning, so its speed is slow; the second algorithm always produces poor accuracy of the edge location because of the disturbing signals; while, the third algorithm can overcome the deficiencies of the first two algorithms[4].

The original point cloud data of the cultural site scenes are immense. In addition, there are not only ancient buildings, outbuildings but also large amounts of invalid data like the trees, sign posts and other shelters between the laser scanner and the measured objects, and the scattered points while laser penetrates the transparent objects in the

[4] Ai-wu ZHANG, et al, “Basic Processing Methods of 3D Geometrical Signals from Large Scale Scenes,” *Journal of Computer-aided Design & Computer Graphics*, 2005, 17(7): 1486–1491.

site scenes. Therefore, the segmentation of this kind of large scale 3D scenes is extremely difficult and till now there exists no systematic engineering approach to realize it. In effect, the rough segment-ation of the site scenes is considered helpful to extract the central buildings or the large outdoor cultural relics to be interested.

Based on the above analysis, this paper proposes the rough segmentation algorithm of the large scenes, which, according to the signal intensity distribution of the scanning echo, is to rapidly extract the aimed object through filtering the invalid signals. This algorithm can be realized as follows:

First, to collect and analyze the signal intensity distribution of the scanning echo of the site scenes so as to define the threshold value section of the valid signals of the aimed object;

Then, to filter the point cloud data of the site scenes according to the following rules: to take the data of the distance signal values between the $\left[d_{mi}-\delta_1, d_{mi}+\delta_2\right](\delta_1>\delta_2)$ as the aimed object and retain all data; to take the data of the distance signal values between the $\left[0, d_{mi}-\delta_1\right)$ as the shelters of the aimed object and retain as useful data; and to take the data of the distance signal values between the $\left(d_{mi}+\delta_2, +\infty\right)$ as scattered points when laser penetrates the transparent objects and delete them as invalid data.

This algorithm is essentially the technology of edge segmentation. Although its segmentation accuracy is limited, it is simple and efficient and easy to design and carry out. Therefore, it can be used to extract the large cultural relics from the original point cloud data of the cultural sites.

2.3.2. The segmentation process

The experiment object in the paper is the center region of the Small Wild Goose Pagoda, including the body, the base and the small tablet in front of the Pagoda. The point cloud data of the scenes are 20,822,559 points and the data processing platform is Cyclone 5.5. The main process is as described below.

(1) to collect and analyze the distance signal intensity of the laser scanning of the Pagoda

Altogether, in the experiment we select 21 groups of key data which indicate the correlation between the signal intensity and sampling rate, and, according to the results of statistical analysis mapping (signal strength, the sampling rate), draw the correlation curve, as shown below:

Table 1 the (*signal strength*, *sampling rate*) data

Signal strength	0.3800	0.4021	0.4124	0.4179	0.4258
Sampling rate	0.00	5.11	10.11	15.02	19.04
Signal strength	0.4359	0.4417	0.4491	0.4564	0.4682
Sampling rate	32.35	43.13	55.86	65.40	80.40
Signal strength	0.4775	0.4799	0.4887	0.4961	0.5181
Sampling rate	93.29	95.49	98.32	99.22	99.90
Signal strength	0.5255	0.5358	0.5534	0.6180	0.6342
Sampling rate	99.94	99.97	99.98	99.98	99.99
Signal strength	0.6870				
Sampling rate	100				

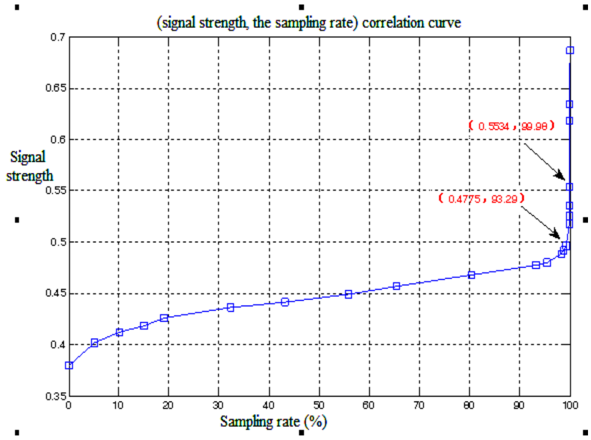


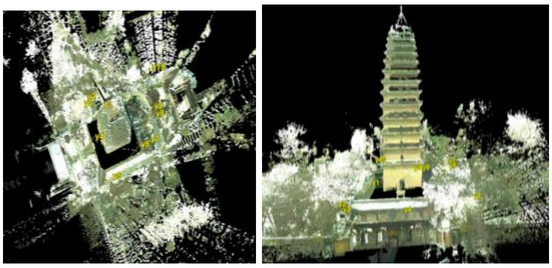
Figure 6. (signal strength, sampling rate) correlation curve

(2) to determine the threshold value range

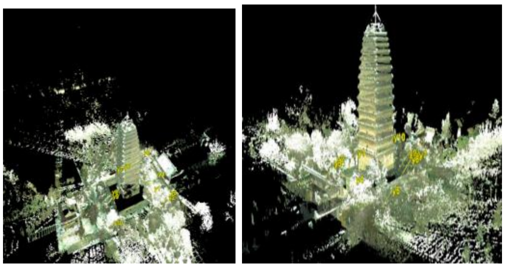
According to the (signal strength, sampling rate) correlation curve, the intensity distribution of the laser echo signal of the Small Wild Goose Pagoda should be constricted to $\left[0.4775, 0.5534\right]$.

(3) to trigger the filter process of the pre-defination according to the determined threshold value section

With the sampling rates of 93.29%～99.98 as the premises and basing on the rough algorithm of the large-scale scenes, we extract the main part of the Small Wild Goose Pagoda (including the tablet in front of the Pagoda) successfully and achieve comparatively ideal segmentation, as shown in the following figures.

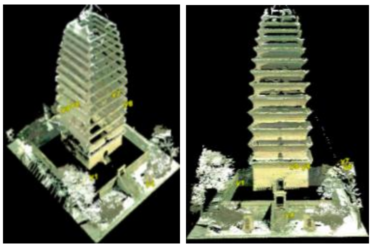


(a) Top view (b) Front view

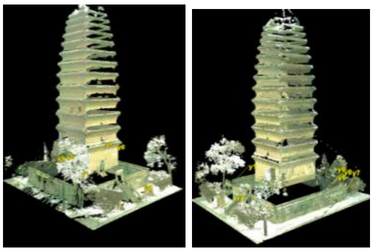


(c)Left view (d)Right view

Figure7. The original point cloud



(a) Top view (b) Front view



(c)Left view (d)Right view

Figure 8. The segmentation result

2.4. 3D geometrical modeling

In the 3D geometrical modeling, there are mainly two methods which are the volumetric method proposed by Sequeira and Turk and the mesh method proposed by Curless and Levoy.

The disadvantage of volumetric method is that the local registration error will affect the modeling accuracy, and can not smooth the registeration errors caused by multiple 3D registration. In addition, the mesh method can identify holes and automatically distinguish the points which are not from the same object[5].

According to the law of geometrical symmetry of the ancient architectures,the *3D Model Repairing System*, which was developed by the Visual Technology Institute of Northwest University, is adopted to repair the mesh model of the Small Wild Goose Pagoda. When the holes are in the plane area, the linear interpolation method is used to fill in the missing data, such as the holes in the windows and the walls of the ancient buildings; when the holes are in the non-planar area, such as the holes on top of roofs, the quadric interpolation method is used[6]. We construct the 3D geometric model of the main part of the Small Wild Goose Pagoda by using the system and achieve satisfactory results, as shown below.

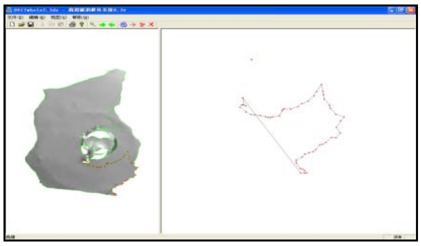
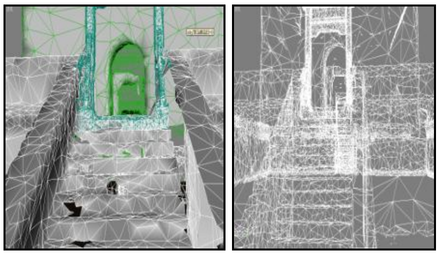


Figure 9. The Hole Repairing System

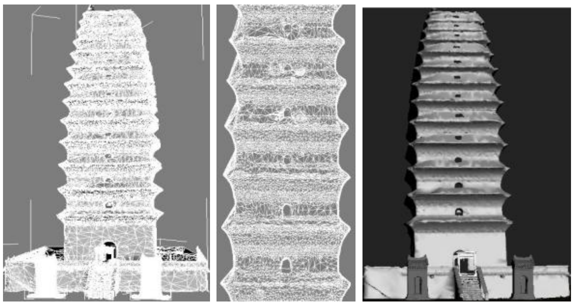


(a) Before holes repair (b) After holes repair

Figure 10. Holes repairing experiment

[5] Shao-xin HU, et al, "Modeling Method for Large-scale Cultural Heritage Sites and Objects Using Real Geometric Data and Real Texture Data," *Journal of System Simulation*, 2006, 18(4): 951–954.

[6] Xin CHENG, et al, "Hole-filling Method for Reconstruction of Triangular Mesh," *Application Research of Computers*, 2006, (6): 158–159.



(a) Mesh model (b) Surface model

Figure 11. Geometrical model of the Pagoda

2.5. 3D texture mapping

In the existing texture mapping methods, the camera parameters cannot be acquired accurately, which would limit the accuracy of texture mapping. From the perspective of engineering applications, there is no 3D texture mapping method of the large scenes which can achieve realistic effects as digital photography technology can. We use *the two-step method* which is based on the synchronized visual image and laser scanning data to implement the texture mapping of the 3D models of the cultural sites.In the method,the laser data and the synchro-nized visual image are calibrated at first. Second, the camera parameters are estimated.Then,utilizing the laser-synchronized visual image as one kind of integrations, the global and local mapping error distributions between higher resolution texture image and laser scanning data are calculated. Finally, using the calculated error distribution,the higher resolution textures are mapped to the 3D model[7].

The key of the method is how to obtain the true mapping points and the mapping error of the data points. We divide the work into the following three stages, firstly you should select some feature points manually at the global processing stage, and the more feature points would be extracted automatically based on the previous data sets at the local processing stage, and then the mapping error would be estimated by combining the dual tuner spine interpolation and bilinear interpolation method. The main flow of the two-step method is shown in figure 12.

[7] Xin JIN, et al, "Texture mapping of 3D scenes based on the laser-synchronized visual image," *Chinese Journal of Scienific Instrument*, 2006, 27(6): 2083–2085.

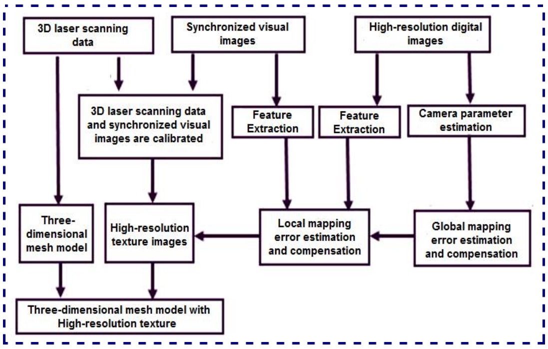


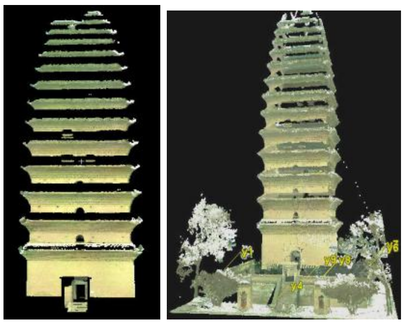
Figure 12. The two-step method

In the simulation experiment, 670 measuring points are used to calculate the mapping errors before and after the use of *the two-step method*, and the results are shown in table 2. The experiment results show that, after error compensation, the horizontal and vertical errors have been greatly reduced and the error distribution concentrates in the range of around 0, which indicate that the accuracy of texture mapping has been improved evidently.

Table 2 The mapping error comparison between Non compensation and G-L compensation (pixels)

	Non error compensation		Global error compensation		Local error compensation	
	Mean	Variance	Mean	Variance	Mean	Variance
Horizontal error	4.55	5.86	2.30	2.89	0.79	1.33
Vertical error	4.16	4.13	1.96	2.44	0.63	1.03

We achieve the 3D texture mapping of the main part of the Small Wild Goose Pagoda by using the laser-synchronized method, as shown in figure 13.



(a) By the Cyclone method

(b) By the laser-synchronized method

Figure 13. The texture mapping experiment result

2.6. 3D site scenes modeling

As we know, although the design or modeling packages can help the users to create entirely novel models from a conceptual model or idea quickly, the models often have little to do with reality. The reason is that most CAD softwares construct geometrical models from only a few sample vertices and estimate the rest with design assumptions. As the ancient buildings of the cultural heritage sites always have narrow and complex structures, it is difficult to characterize the precise geometry of a small number of sampling points. Evidently, this method can not reconstruct the realistic models of the cultural herigate sites construction. Therefore, We believe that the correct approach should be obtained to calculate the geometrical parameters by using the 3D space measurement method[8] based on the original point cloud data and by combing the texture information of the cultural sites.

Basing on the Cyclone 5.5 paltform, which can provide a high-performance environment for manipulating point cloud data captured by High Definition Surveying (HDS™)3000 systems and can enable the users to accurately measure 3D objects in the scenes, we get a series of building's profiles by cutting the laser scanning point cloud data and reconstruct the 3D models of the most ancient outbuildings of the Small Wild Goose Pagoda by using 3D Max9.0, as shown in figures 14～19.

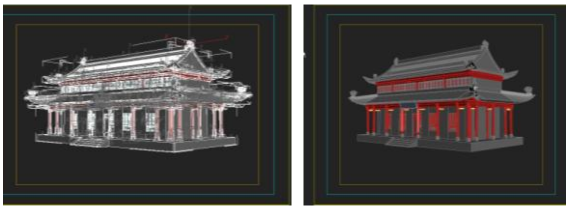
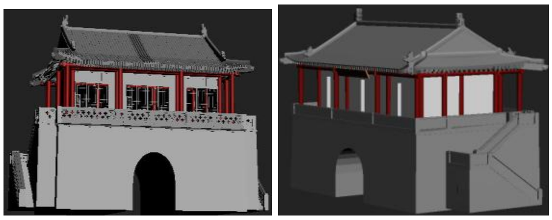


Figure 14. Light SANQIN model（139,195Polys）



(a) Fine（3,133,779Polys） (b) Simplified（47,554Polys）

Figure 15. White tower in Ming Dynasty models

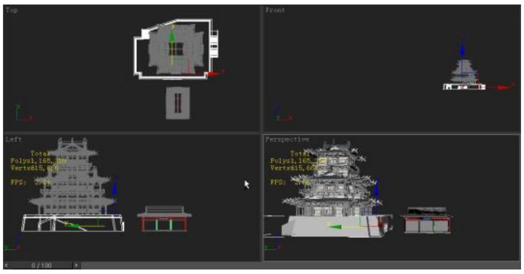


Figure 16. Freehand court model（1,165,359Polys）

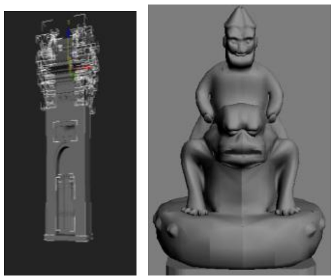


Figure 17. Outdoor heritage model

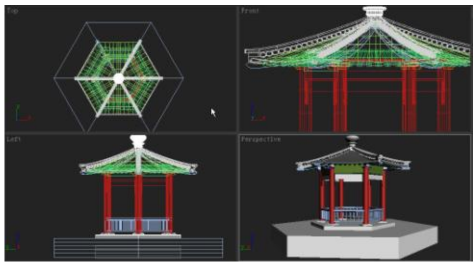


Figure 18. Ancient pavilion model（67,592Polys）

[8] Guo-hua GENG, et al, "Interactive Space 3D Distance Measurement," *Journal of Northwest University (Natural Science Edition)*, 2000, 30 (4): 296–299.

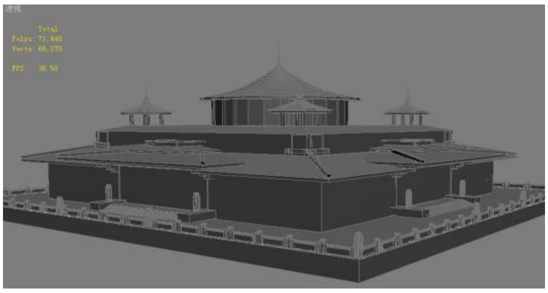
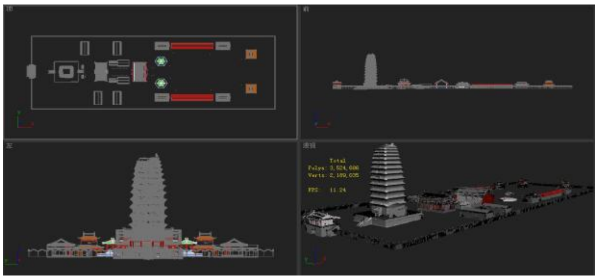


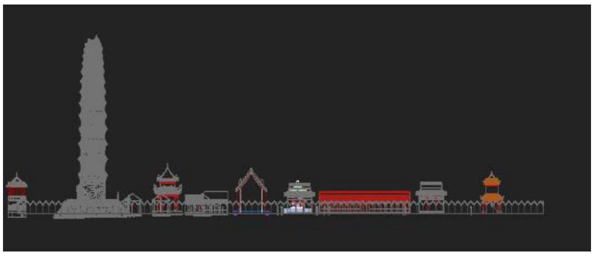
Figure 19. Xi'an Museum model

The research team members make all efforts to accurately reconstruct the 3D realistic scenes model of the Pagoda body and create the 3D superficial model of the ancient outbuildings of the heritage sites in a short time.

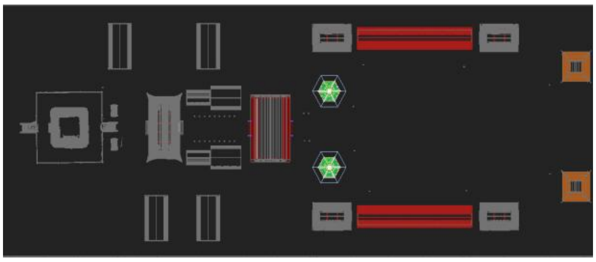
Based on the above results, the sub-scenes are combined. The 3D virtual scenes model of the Small Wild Goose Pagoda is shown in the following figures.



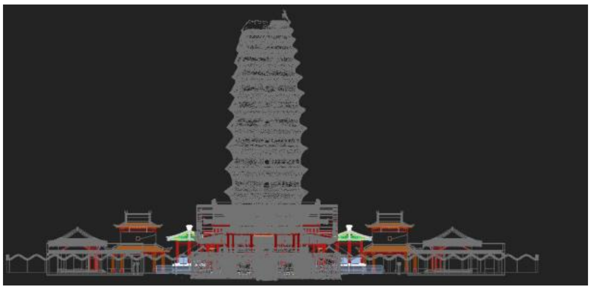
(a) Full view



(b) Left view

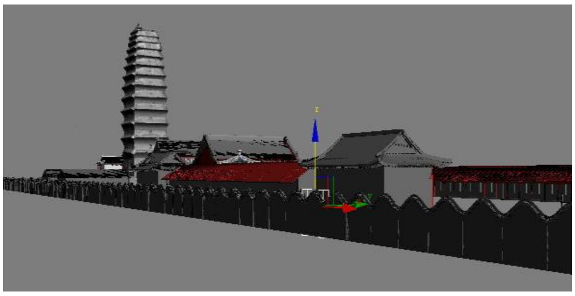


(c) Top view



(d) Front view

Figure 20. The scene views of the Small Wild Goose Pagoda



(a) Left view

(b) Right view

Figure 21. The scenes model of the Small Wild Goose Pagoda

3 3D virtual walkthrough system

1.2. Requirements analysis

In recent years, the increasing investments on the preservation of the key cultural relics make the 3D laser scanning technology and the virtual reality-based technology widely used in the digital preservation of the cultural relics[9]. In addition, several virtual display projects of famous cultural relics have been arranged, like the digital preserva-tion and virtual travel of Dunhuang art, 3D virtual display of Forbidden City, the restore of Beijing in

[9] George Sidiropoulos, et al, “Ultra-real or symbolic visualiz-ation? The case of city through time,” *Computer & Graphics*, 2006, 30: 299–310.

Qing Dynasty, etc. These key projects emphasize the sense of reality and the sense of immersion and are mostly based on high-performance graphic workstation and expensive display equipments such as CAVE (Cave Automated Virtual Environment), the annular screen, the dome screen, etc.

At the same time, although archeologists and travelers can conveniently visit the websites and obtain the relative information which they are interested in, they can only achieve the text, image and video of the cultural sites. With the development of the GIS and VR technology, a huge demand for the new system is rapidly emerging. The system should help travelers to visit the 3D virual scenes of the cultural sites by using the GIS method, and should be released on the Internet[10]. We name it 3D-based Cultural Heritage Virtual Display System (CVDS^{3D}).

1.3. System architecture

The CVDS^{3D} system is designed to provide the public the spatial information query and 3D visual display for the cultural sites. The system should be based on the service oriented architecture (SOA) so as to balance the network load and achieve the maximum response speed. Then, the system uses the N layer and B/S structure mode, which can be divided into the presentation layer (also called the user interface layer), the function layer (also called business logic layer), the data layer (also called data services layer) and the database layer[11]. In order to fastly realease the applications and avoid the difficulties of version control, we develop the system based on the Net platform. The framework is shown in Figure 22.

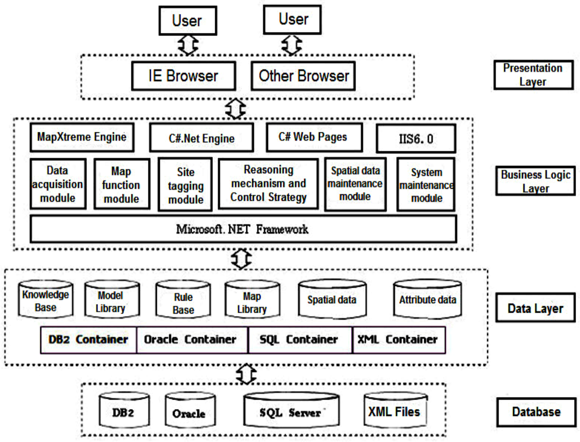


Figure 22. The framework of CVDS^{3D}

1.4. Creating virtual walkthrough object

By using the external creative interface (EAI) of the middleware platform, called Virtual Reality Platform (VRPlatform)8.0, the system provides the interactive walkthrough of the 3D virtual scenes of the cultural heritage sites. The specific process is as follows:

In the first place, you should input the 3D model of the Small Wild Goose Pagoda site scenes into the VRPlatform. Then, basing on the VRPlatform, you should set the illumination, cameras and roaming path of the virtual scenes, and then render and bake in order to enhance the realistic scenes, as shown below.

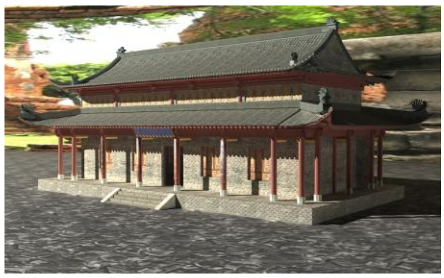


Figure 23. Light SANQIN realistic model

Using the above method, we create a vitual 3D object of the Small Wild Goose Pagoda scenes which can be realesed based on the Internet, as shown below.

[10] Bonfigl M., et al, "Virtual visits to cultural heritage supported by web-agents," *Information and Software Technology*, 2004, 46: 173–184.

[11] Amnon H., et al, "Architecture,design, implementation" (Proceedings of the 25th International Conference on Software Engineering, 2003): 149–159.

(a) The loading interface of the virtual object

(b) The scene after rendering and baking

(c) Aerosol effect of the tower regional

Figure 24. The 3D virtual walkthrough object of Small Goose Pagoda

1.5. The Virtual walkthrough mode

Based on the VRPlatform8.0, CVDS3D system is designed to provide the following virtual walkthrough modes[12], as shown below.

(1) *Automatic guide mode*, to provide users with the best tour path which is well-designed visually, and with the three-dimention virtual display service of the cultural site scenes, as is shown in figure 25(a).

(2) *View selection mode*, to provide a set of prepared camera locations to users who can select a particualar camera to visit the intersting buildings or outbuildings in the virtual scenes, as is shown in figure 25(b).

(3) *Interactive roaming mode*, to provide users with the mouse or touch screen or other equipments so that they can control the direction and adjust the viewpoint to roam the virtual scenes freely, as is shown in figure 25(c).

(4) *Intelligent roaming mode*, to provide users, who only need to decide their starting point and the destination, with an algorithm which will automatically generate the shortest tour path for them and display the three-dimention virtual site scenes by using the automatic guide mode.

(a) Automatic guide mode

(b) View selection mode

(c) Interactive roaming mode

Figure 25. The 3D virtual walkthrough mode

4 Conclusions and future work

In the aspect of the engineering application, the research team operate the post process of the point cloud data of the Small Wild Goose Pagoda,

[12] Hong-xia LI, "The Human Computer Interaction Approach with Virtual Three-dimensional World Based on Web," *Journal of Northwest University(Natural Science Edition)*, 2002, (1): 26–29.

including the registration of the original point cloud, the segmentation of the site scenes, the simplification of the point cloud and the reconstruction of the geometrical mesh, etc., then, found a reality-based 3D digital modeling of the Small Wild Goose Pagoda, next, implement the digital preservation of this important cultural heritage built in 707 A.D. and finally put forward a set of practical technological programs according to the project implementation.

In the aspect of the software development, aiming at the 3D virtual display of the cultural sites based on network, the research team researchand put forward the system framework, technical roadmap and implementation methods, then design and implement the Cultural Heritage Sites Virtual Display Systems 3D- based(CVDS^{3D}) which will have a great value of application. We also create a digital object with 3D virtual walkthrough function for the Small Wild Goose Pagoda so that people can enjoy and spread its unique historical, cultural and tourist values‰ on the Internet.

The future work should include the following aspects:

The method of the fast global registration of outdoor large-scale scenes should be further explored.

The algorithm of the 3D texture mapping of the large-scale and complex scenes should be further improved.

The integration methods of laser scanning technology and close range photogrammetric technology should be further researched.

The 3D virtual walkthrough prototype system for the cultural sites should be more practical.

Acknowledgements

The work reported in this paper was founded by the National Natural Science Foundation of China (grant number 60873094), by the Key Research Project of Weinan Teachers University (grant number 09YKF007), and by the Key Laboratory of Cultural Heritage Research and Conservation (Northwest University), Ministry of Education of China. The research team would also wish to thank the scholars of the Cultural Relics Bureau of Xi'an for their assistance of gathering information on the Small Wild Goose Pagoda. The authors also wish to thank the anonymous reviewers for their helpful and constructive suggestions.

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