Virtual Reality Technique-based Digital Restoration of Chinese Ancient Architectural Scene

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Abstract

By introducing the function of virtual reality technology, this paper starts with the feature of Chinese ancient architecture and takes Yuanmingyuan Imperial Garden, a building in Qing Dynasty, for the research object, to present a key introduction of the system design process in which virtual reality technology is used to reconstruct building landscape. The system includes reconstruction system, real-time rendering system and roam system; the lifelike virtual result proves that virtual reality technology, with an obvious application effect in the reproduction of building landscape, is worthy of approval and promotion.

Keywords: virtual reconstruction; rendering system; roam system; Yuanmingyuan Imperial Garden

1 Introduction

Virtual reality technique is a comprehensive discipline, which covers such technologies as computer graphics [1-3], digital image processing, computer vision and system control, etc. In the process of simulating physical geography and humane historical sites, the use of this technique can create a lifelike virtual world by adopting electronic computer's massive computing power and image processing capacity. So the positive role of virtual reality technique in researching and publicizing humanity history and physical geography is acknowledged widely in the international society [4-6].

2 Project Context

2.1 THE FEATURE OF CHINESE ANCIENT ARCHITECTURE

Chinese ancient architecture is of stone-wood structure. The architectural decoration is fine and shape is unique, such as color painting, cornice, carving decoration and corbel bracket. The architectural layout has a strong sense of beauty [7-10]. The complex is composed of units, the unit is composed of courtyards, and the courtyard is composed of "rooms". "Room" is the smallest unit of ancient architecture.

Since wood and brick are susceptible to natural environment, water, fire and temperature, the remaining ancient buildings should be maintained and decorated with high attention. But due to the missing of some materials and installation technology as well as the baptism of time, it's basically difficult to restore the original appearance of the ancient buildings. Virtual reconstruction can display the original appearance of the ancient buildings through computer technologies and normal data.

2.2 THE CAUSE FOR THE CHOICE OF YUANMINGYUAN IMPERIAL GARDEN AS THE OBJECT OF RECONSTRUCTION

Yuanmingyuan Imperial Garden is a landscape garden built by Emperor Kangxi and extended by Emperor Qianlong, where the imperial family of Qing Dynasty avoided summer heat and handled political affairs in the past time. Most of the architectural complexes, such as palace, wharf, temple, imperial burial place and opera house, were used for a special purpose. It was one of the most famous royal gardens in ancient China. Yuanmingyuan Imperial Garden fell into ruins owing to the unbridled havoc of the Eight-Power Allied Forces. The profile of the entire garden was also damaged severely.

This paper chooses Yuanmingyuan Imperial Garden as the object of reconstruction for the following reasons: firstly, it was a famous imperial garden at the highest construction level in the world at that time; secondly, it witnessed Qing Dynasty's backwardness and vulnerableness to attacks, so it's a good teaching material for national defence education. There hasn't been a uniform opinion in the society on the reconstruction of Yuanmingyuan Imperial Garden, but there is another difficulty that the ruins of Yuanmingyuan were burnt down, with few remains of base and little text and video data left, so it's hard to build a model, and it's difficult to restore the historical appearance of Yuanmingyuan Imperial Garden on those historical bases. Someone will consider the reconstruction of Yuanmingyuan Imperial Garden to be the erasing of "national humiliation".

So the virtual reconstruction of Yuanmingyuan Imperial Garden can not only make it unnecessary to modify the ruins of Yuanmingyuan Imperial Garden in the

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base, but also show the original appearance of Yuanmingyuan Imperial Garden in virtual computer, for the countrymen to appreciate the artistic beauty of Yuanmingyuan Imperial Garden [11-13]. Under the intuitive guidance of virtual reconstruction technology, the future real reconstruction can avoid massive losses caused by the missing of historical data.

3 Design of a Virtual Reconstruction System

The virtual reconstruction of Yuanmingyuan Imperial Garden is that use is made of computer technique to reconstruct the royal garden in the virtual world based on the situation of the ruins and the restoration of the cultural relics. By doing so, we can propagandize our country's outstanding cultural relics and tell audience the historical events and the country's development status; it's feasible, in the premise of keeping the culture heritages in the current condition, to display the scenes of Yuanmingyuan Imperial Garden in different times. This work can provide reference data for the practice of architecture.

The systematic design in this stage is to reconstruct individual landscapes by analyzing data, to draw a lifelike roam track in computer.

3.1 RECONSTRUCTION METHOD

Usually, the following methods can be used for reconstruction: field measurement, hand-made modeling, panoramic photomosaic and model import. It's very difficult to reconstruct Yuanmingyuan Imperial Garden. Firstly, there isn't ready-made digital modeling for reference due to the long time interval; secondly, field measurement and panoramic photomosaic are impractical since the garden was damaged by the Eight-Power Allied Forces. So only hand-made modeling can help to complete virtual reconstruction.

About the visual construction of Yuanmingyuan Imperial Garden, we first go to the ruins of "Jiuzhouqingyan" to obtain basic data and design environment variables for the various scenic spots according to the historical relic *The Forty Landscapes in Yuanmingyuan Imperial Garden*. School of Architecture and Design of Tsinghua University supplies technical support for the building of digital model for each unit. And use is made of 3DMax to integrate such data as the profile and texture of the buildings into the rendering system.

3.2 REAL-TIME RENDERING SYSTEM

3.2.1 The choice of rendering engine

In this project, OGRE (Object-Oriented Graphics Rendering Engine) is chosen as a rendering engine. OGRE is a 3D image rendering software. If R&D engineers use object-oriented language C++ for development, they can directly devise application software. In this case, they will not need to use such underlying system libraries as OpenGL and Direct3D. For OGRE design mode, firstly, it has strong scene management functions and rich system scripts; secondly, it provides an efficient object-oriented interface, which has a strong expansibility. In addition, it has rich graphics features, able to meet automatic picture processing requirements, to improve the efficiency and quality of rendering and drawing. Besides, ORGE unwrapped source code has complete development systems, able to meet different projects' need for uniqueness. OGRE's rendering process is show in Fig. 1.

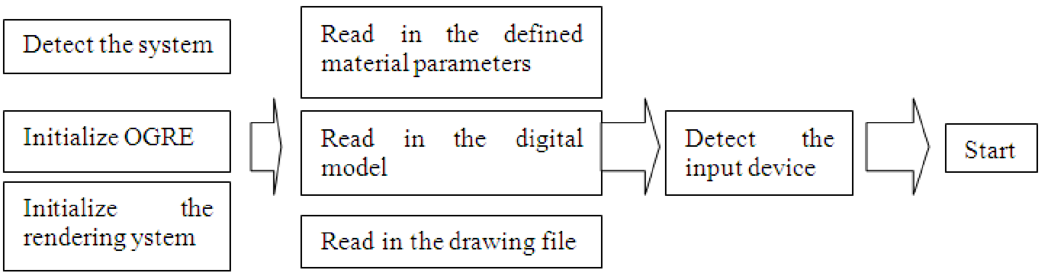

FIGURE 1. rendering flow chart of drawing engine

In rendering process, basic model is made with 3DMax, and saved as mesh file with the use of Octupus plug-in. Such an OGRE can be read and written. Use can also be made of 3ddotscenemanager plug-in to make and modify the whole scene of Yuanmingyuan Imperial Garden. Here, its' feasible to revise and set some basic parameters for the animation effect of light, scene and landscape in OGRE. This time, we can select a scene management system for outdoor scenes and choose octree storage as a data structure to handle the scenes. This is conducive to data handling and storage.

3.2.2 The environmental effect of real-time rendering process

An overall visual effect can be created for outdoor scenes through such factors as sky, ground, weather and horizontal plane. For sky, there are three major construction methods: skybox, plane sky and sky dome. Here, sky dome is adopted for easy observation. Ground mainly contains such surface features as terrain, horizon, vegetation and landform. Elevation grey-scale map can reveal the ups and downs of the landform, with high elevation represented by a light color and low elevation represented by a dark color. OGRE describes a grid chart for the up-and-down landform by reading the gray value of each pixel, and then, distributes the predefined terrain textures in the grid chart, to form many complete and vivid effect pictures of landform.

Visual effect picture is generally created for weather through wind, rain, fog and snow. For this project is drawn by the use of particle system. OGRE engine particle system mainly includes such important attributes as color, diversion, quantity, shape, texture and weight. Particle system is composed of particle affector and transmitter. Particle affector is predefined by the above parameters. There are two kinds of particle transmitters: dot-mode particle transmitter and box-mode particle transmitter. They can send particles to a target scene. It's easy and convenient to adjust and define particle transmitter, with no need for compiling, but for setting relevant parameters in scripting language. OGRE has a critical function, that is, it can manage particle pool automatically, to expand particle system's application range and accuracy greatly.

Horizontal plane mainly has two effect pictures: reflection and refraction. When light gets out of a substance and into another, due to the difference of angle and substance attribute, it will be reflected and refracted. Through a study of Fresnel reflection method, we learn the different proportions of specular reflection and scattering in reflected light. Here, we define *Fs* as the component of parallel polarized light, *Fp* as the component of vertical polarized light, a as the angle of incidence θ, *b* as the refractive index of both kinds of substances, and # as the refractive index constant of both kinds of substances.

$$\eta = \frac{\eta_A \eta_B + k_B k_A}{\eta_A^2 + k_A^2}; \quad k = \frac{\eta_A k_B - \eta_B k_A}{\eta_A^2 + k_A^2};$$

$$2a^2 = \sqrt{4k^2\eta^2 + (\eta^2 - k^2 \sin\theta^2)^2} + (\eta^2 - k^2 - \sin^2\theta)$$

$$2b^2 = \sqrt{4k^2\eta^2 + (\eta^2 - k^2 \sin\theta^2)^2} - (\eta^2 - k^2 - \sin^2\theta)$$

$$F_s = \frac{a^2 + b^2 + 2a\cos\theta - \cos^2\theta}{a^2 + b^2 - 2a\cos\theta + \cos^2\theta} \quad (1)$$

$$F_P = F_S \frac{a^2 + b^2 + 2a\sin\theta\tan\theta + \sin^2\theta\tan^2\theta}{a^2 + b^2 - 2a\sin\theta\tan\theta + \sin^2\theta\tan^2\theta} \quad (2)$$

Both Formula (1) and Formula (2) are used to calculate reflection and refraction effects under Fresnel law. Incident light is non-polarized. So, reflex can be calculated by the mean value $F = \frac{F_S + F_P}{2}$ of two kinds of polarized light.

In rendering process, different dynamic textures are defined to express reflection and refraction effects. Here, a programmable GPU should be used to improve computational efficiency. People often overlook water, so they can get a visual angle of air going into water. The data irrelevant to people's angle of incidence θ can be predefined before rendering, and the data relevant to the angle of incidence θ can embed in GPU automatically in the process in which render engine is started. When frame listener finds a change in people's view of angle, GPU can calculate each fixed point's dynamic texture value, and then work out the textural features of the overall water level through linear interpolation processing.

The render effect in Fig.3 shows that if the angle between man's line of sight and water level is near to 180°, the reflection effect will be better; if the angle between man's line of sight and water level is near to 90°, the refraction effect will be better. This is the application effect chart obtained through Fresnel reflection method.

3.3 ROAM SYSTEM

For the virtual reconstruction system here, such three methods as independent roam, oriented roam and limited roam can be adopted.

3.3.1 Independent roam

The advantage of independent roam is that customers can roam along any line in any virtual scene according to their personal motive, to achieve a personalized effect. For instance, from an overhead view, customers can leap up from the ground to control the architectural layout below, to achieve a good virtual roam effect. When users want to observe some partial building carefully, they can observe its personality characteristics at short range. The shortcoming is that deviations are easily caused. Customers may roam into a building or go beyond the scope of the simulated object when flying.

3.3.2 Limited roam

Limited roam refers to that a rational limit is prescribed to some specific customers and scopes when they roam freely, to achieve a desired roam effect. To prevent roamers from getting into a building, the system sets a collision detection mechanism; to ensure that roamers will not fly beyond the range of visibility, the system sets a certain height, to restrict them from advancing at the extreme boundary.

3.3.3 Oriented roam

Oriented roam refers to that designers or system administrators will preset some rational routes, to guide customers to roam along the specified routes as required. Its advantage is that the system can automatically calculate a good route map to guide customers to roam.

After system administrators set a location and angle of view for the key frame, the system can automatically connect roam routes. Key frame parameters include coordinate, rotation angle, scaling and roam time point. When users roam, according to the current time, they can connect the interpolations and intervals of the key frame in front and back, to automatically calculate the significant attributes of the current frame.

Here, we can set a rational roam speed for customers, trying to let them obtain the roam contents they need. However, roam effect will be affected by computer performance. In a computer with good performance, customers can see more frames. In this case, they will see a coherent and fluent screen.

When roaming, customers can adjust the angle of view among the interval frames as required, or predefine according to the visual angle of key frame. Here, predefinition is used to set linear interpolation. Let the angle of view of the k^{th} key frame point be θ_k and time point be T_k; the angle of view of the $(k+1)^{th}$ be θ_{k+1} and time point be T_i; the computational formula for the visual angle of the interval frame at T_i time point:

$$\theta_i = \theta_k + (\theta_{k+1} - \theta_k)\frac{T_i - T_k}{T_{k+1} - T_k} \quad (T_k < T_i < T_{k+1}) \tag{3}$$

Calculate the interpolation of viewpoint's moving trajectory by the use of linear interpolation. There is often an inflection point in the key frame, and here what is adopted is spline interpolation method. OGRE's encapsulated SimpleSpline class handles the interpolation of displacement and proportion; RotationSpline class library can calculate rotation interpolation.

The effect of oriented roam is similar to movie. The strength is that since it has many predefinition programs, it can achieve a lifelike roam effect, it has many objects to pre-render, and it has a strong processing capacity; the disadvantage is that its interactivity with customers is low.

4 Graphic Effect Analysis

Figure 2 shows the effect picture of virtual scenes. A desktop computer is adopted, the CPU is P4 2.8GHzCPU and the graphics card is graphics card. When customers roam, FPS is higher than 19. For the effect picture in Tab.1, the monitor resolution is 800×600, and OpenGL system is used to render the various scenes.

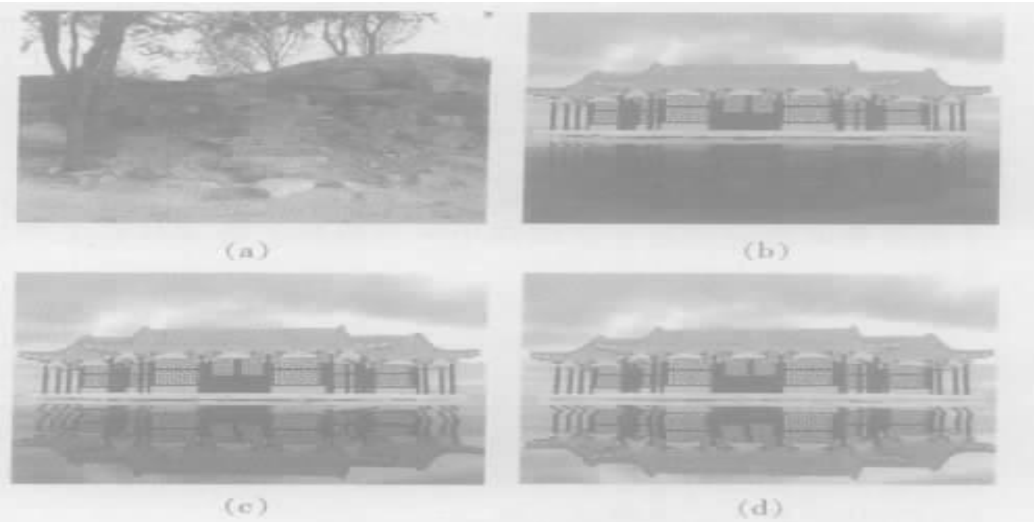

FIGURE 2 Jiuzhouqingyan main palace and its reflection

Figure 2(a) shows the present situation of the ruins of the main hall of Jiuzhouqingyan, and Figure 2 (b) to (d) show the effect picture of virtual reconstruction. From Figure 2 (b) to (d), customers' visual angle tends to be horizontal gradually, so the picture becomes increasingly clear.

Table .1. The render effect of different scenes

Architecture scene	Material quantity	Triangle number	Average FPS
Qinghui Pavilion	20	48000	24.2
Festoon gate	14	32000	25.3
Jiuzhouqingyan (with a horizontal plane)	32	30600	23.6
Jiuzhouqingyan	30	30500	44.3
Hanbi Hall	23	66000	27.6

Frame rate is decided by the number of polygon, water reflections and the number of light source. When customers roam on water, the mean frame rate of real-time roam will drop by about 10 frames per second.

5 Conclusion

The use of virtual reality technology to reconstruct Yuanmingyuan Imperial Garden can restore the original prosperous scene of Yuanmingyuan Imperial Garden on the basis of not changing the original appearance of the ruins. In this way, the contradiction between the reconstruction of Yuanmingyuan Imperial Garden and the preservation of historical relics can be solved. But due to the limits of the times and the missing of most historical documents, it's impossible to show the original appearance of all the buildings in Yuanmingyuan Imperial Garden. After we have mature technical conditions, we can divide the whole garden into different parts and then subdivide the parts into different units, for a step-by-step virtual reconstruction, to form a complete and vivid virtual Yuanmingyuan Imperial Garden landscape.

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