Research on 3D Rendering Effect under Multi-strategy

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Abstract—With the development of computer hardware and rendering methods, efficient and high-quality 3D rendering strategies have become the focus of current research. This paper takes hardware configuration and rendering methods as variables to explore the rendering effects of materials, textures, lights, accuracy, etc. of different 3D models. With Cycles rendering, LuxRender rendering, and Octane rendering as the rendering methods, multiple rendering strategies are formed on multiple clients such as servers and hosts. Through the comparative research of multi-strategy 3D rendering effects, the optimal strategy of model rendering is proposed, which integrates the rendering time, rendering effect, and rendering cost. Multi-strategy 3D rendering effect research can provide some ideas and solutions for current 3D rendering.

Keywords-Three dimensional; Rendering method; Multi-Client Rendering; Multi-strategy rendering; Rendering Effects

1 INTRODUCTION

With the development of computer vision and computer graphics, computers have gradually become capable of human vision [1]. One important aspect of computer vision is to map the simulated 3D scenes and 3D models into rendering pictures through space coordinate transformation [2], that is, 3D rendering. At present, high-quality 3D rendering processes are widely used in animation, movies, games, home decoration, and other industries. Real and shocking effects can enhance the value of industries and products. 3D rendering is calculated in seconds or frames, which requires a special graphic renderer. A high-quality rendering effect of a frame requires a better renderer and more time [3]. Therefore, rendering effect and rendering time have become major bottlenecks in the development of 3D rendering technology. In this paper, hardware configuration and rendering methods are used as variables to explore efficient and high-quality rendering strategies. With server and client as rendering hardware, multiple rendering methods form the optimal strategy on multiple ends and the shading effects of materials, textures, lights, accuracy, etc. of different 3D models are tested. Through the cooperation of hardware configuration and rendering methods, different scenes and different models under multiple strategies are formed, providing some new ideas for current 3D rendering.

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2 3D RENDERING

2.1 Three stages of rendering

Rendering is an important step in computer graphics, which is to convert model elements in three-dimensional space into a grid form of computer display and display them on the screen. In the process of 3D rendering, it is necessary to comprehensively consider the material, lighting, texture, and other information of the model and map the model or scene through the visual area of the camera's field of view [4]. The process of 3D rendering can be divided into three stages: from the application stage to the geometric stage, the rendered entities can be output; from the geometric stage to the rasterization stage, the vertex information in screen space can be output; finally, the vertex information output in the geometric stage can be generated into pixels [5] in the rasterization stage, after that, the 3D model effect can be rendered to the screen. The three stages of 3D rendering are shown in Figure 1.

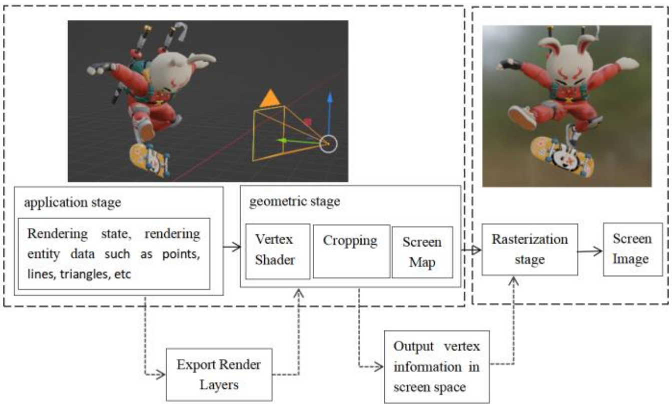

Figure 1. Three stages of 3D rendering

2.2 Coordinate transformation

Of the above three stages of 3D rendering, the most important stage is the geometric stage. The vertex coordinates in the geometric stage need to undergo the multi-coordinate transformation from model space coordinates to screen space coordinates. The process of vertex space coordinates change is shown in Figure 2.

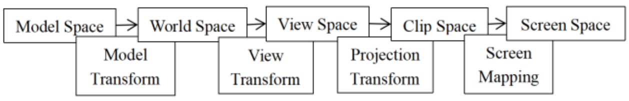

Figure 2. Space coordinate transformation

The coordinate information output in the geometric stage of spatial coordinate transformation is the rasterization stage's input. Interpolate the coordinates and render the effect on the screen pixel by pixel [6]. 3D rendering is a process with a large amount of data calculation and high requirements for the graphic renderer. Based on the above description, it is necessary to consider rendering methods and multi-client rendering to form comparative research of multi-strategy rendering, to obtain the optimal strategy.

2.3 Rendering methods

The 3D rendering effect is directly affected by the rendering methods used. Different rendering methods have their advantages in rendering areas, such as ray tracing, multi-type materials, realistic rendering, and so on. At present, common rendering engines include Mitsuba, Cycles, Octane, LuxRender, Maxwell, V-Ray, etc., which present different rendering effects in material node and view rendering [7]. Different rendering engines apply different scenes and support different rendering forms. The advantages and disadvantages of each engine are compared as shown in Table 1.

Table 1 Advantages and disadvantages of the rendering engine

Rendering Engine	***advantages***	***disadvantages***
Cycles	·Support material node and view rendering ·Supports CPU and GPU rendering ·Support interactive rendering	·Less rendering algorithms ·Cannot achieve caustic rendering
LuxRender	·Support material node and view rendering ·Supports CPU and GPU rendering ·It has post-processing tools with lens effects and noise reduction functions and accurate physical restore capability	·Features such as fur are not supported ·Very slow rendering
Maxwell	·With the function of "multiple lighting", it can change the intensity effect of light ·The picture performance is very unique, with real camera noise effect	·Material node and view rendering are not supported ·Slowest, most noisy
Mitsuba	·Numerous rendering algorithms and sampling modes ·Open source, secondary development possible	·Material node and view rendering are not supported ·Not suitable for formal 3D production process
Octane	·Support material node and view rendering ·Support GPU rendering ·Mesh can be optimized for animation rendering	·Fewer rendering algorithms ·CPU rendering is not supported
V-Ray	·Support material node ·Different optimization options for animation or static frame	·View rendering is not supported

3 MULTI-CLIENT RENDERING

In addition to the design of rendering methods, rendering hardware is also an important factor in rendering effects. Different hardware configurations, such as machine performance, graphics cards, and memory, may affect rendering effects.

3.1 Stand-alone rendering

Single-client rendering is based on the single-host rendering mode. After setting the model parameters [8] of the 3D scene or model, the rendering process is executed through the rendering engine and the host feeds back the rendering results to the rendering result data. As shown in Figure 3, it is a stand-alone rendering process.

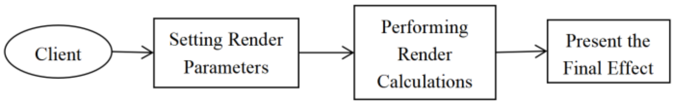

Figure 3. Stand-alone render process

3.2 Server rendering

Server-based rendering is to transfer 3D models, scenes, and animations to the server and the server hardware executes the rendering process. After the execution, the rendering data is fed back to the server and synchronized to customer service [9]. The rendering process on the server is shown in Figure 4.

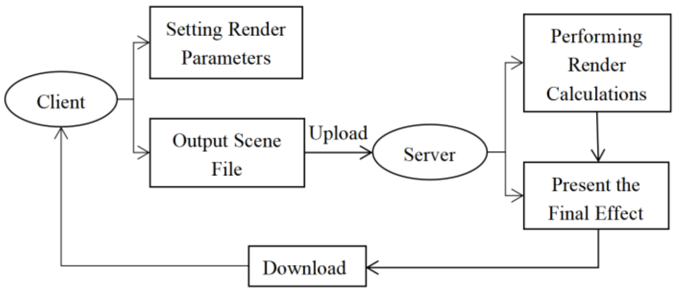

Figure 4. Server rendering process

3.3 Effect comparison of multi-client rendering

Taking stand-alone rendering and server rendering as hardware conditions, consider comparing the rendering effects of two stand-alone clients and one server client using the same rendering engine. The two stand-alone clients used are the same except for their different CPUs. Client I uses the AMD A9-9425 CPU and Client II uses the Core i7-9700F CPU. The purpose is to compare the effects of different CPUs on rendering effects under the same rendering settings. The server-client used supports both CPU and GPU rendering. Here we call it Client III. It aims to compare the effects of hardware configuration improvement on rendering effects under the same rendering settings. Figure 5 shows the rendering scene. Figure 6 shows the rendering time spent by three clients.

Figure 5. Rendering scene

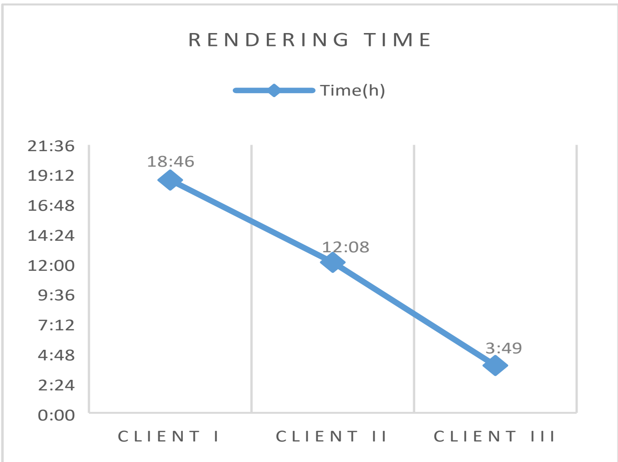

Figure 6. Multi-client rendering time

For the same rendering scene, the effect of the three clients is shown in Figure 7. In Figure 7, A is the rendering effect of client I, B is the rendering effect of client II and C is the rendering effect of client III. According to the comprehensive comparison of the above rendering effects and rendering time, it can be concluded that the rendering effects are related to the hardware configuration. Under the same rendering engine and parameters, the light, material detail, and wrinkle effects of the rendering results are improved with the configuration of the rendering client, while the time required for rendering is less.

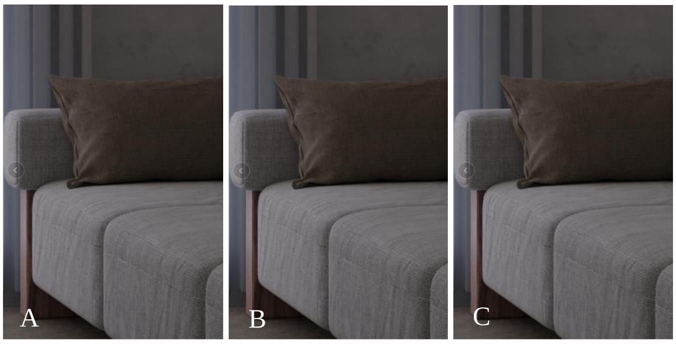

Figure 7. Multi-client rendering effects

4 MULTI-STRATEGY 3D RENDERING EFFECT

The rendering strategy is affected by three aspects. The first aspect is rendering time. Different rendering engines require different rendering times under different hardware configurations, and different rendering materials, such as scenes, models, and animations, have different support for different rendering conditions, so the time required is different. The second aspect is the rendering effect. The rendering engine generates a highly realistic and restorative effect in rendering. The third aspect is the rendering cost. The rendering process generates some hardware costs or rendering engine costs [10]. Next, we will discuss the influencing factors of 3D rendering based on the above three aspects.

4.1 3D rendering strategy

In the process of 3D rendering, there are many factors that affect the rendering effect. This paper uses the control variable method to form a variety of rendering strategies with the client and the rendering method as variables for the same scene and the same rendering settings. It analyzes various rendering strategies in order to practice the differences between different rendering methods on the same client and between different clients under the same rendering method, It provides some reference for 3D rendering methods. The control variable design of the rendering engine and client can form a variety of rendering strategies. The rendering method and the 3D rendering strategy formed by the client are shown in Figure 8.

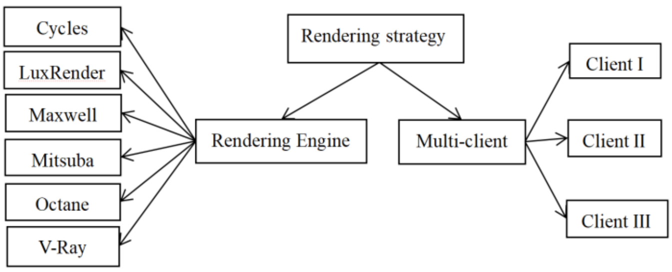

Figure 8. Rendering strategy

4.2 Multi-rendering strategy generation

Mitsuba, Cycles, Octane, LuxRender, Maxwell, and V-Ray rendering engines present different rendering effects in material node and view rendering. Cycles, Octane, and LuxRender rendering engines support both material nodes and view rendering. Other render engines are not friendly to material nodes and render view. Therefore, we choose Cycles, Octane and LuxRender render engines as the rendering methods, Cooperate with three clients to form a multi-strategy 3D rendering effect experimental analysis. The contrast experiment selects modern indoor scenes as the rendering case, highlighting materials, textures, lighting, and other aspects, using a method that supports both material nodes and view rendering. The rendering process tests the computing power of light, material rendering, and rendering noise. According to the Cycles, Octane, LuxRender rendering engines, and three rendering clients, nine schemes are generated. The rendering scheme is shown in Table 2.

Table 2 Rendering strategy

Scheme	***Rendering method***	***Client***
Scheme I	Cycles rendering	Client III
Scheme II	Cycles rendering	Client II
Scheme III	Cycles rendering	Client I
Scheme IV	LuxRender rendering	Client III
Scheme V	LuxRender rendering	Client II
Scheme VI	LuxRender rendering	Client I
Scheme VII	Octane rendering	Client III
Scheme VIII	Octane rendering	Client II
Scheme IX	Octane rendering	Client I

4.3 Rendering effect comparison

Figure 9 shows the rendered scene. The above scheme conducts experiments on the scene and the experimental effect after rendering is shown in Figure 10. A is the rendering effect of Scheme I, B is the rendering effect of Scheme II, C is the rendering effect of Scheme III, D is the rendering effect of Scheme IV, E is the rendering effect of Scheme V, F is the rendering effect of Scheme VI, G is the rendering effect of Scheme VII, H is the rendering effect of Scheme VIII and I is the rendering effect of Scheme IX. Figure 11 shows the rendering time of nine schemes.

Figure 9. Rendering scene

Scheme I, Scheme II, and Scheme III use the Cycles rendering engine to render on different clients. According to the effects of A, B, and C in Figure 10, Scheme I has excellent indoor light processing, material shadow, and reflection processing. The details and levels of light shadow are very clear. Cloth and wood grain materials are rendered realistically, but the overall picture is noisy. The rendering result of Scheme II has a deep color, detailed indoor light processing, material shadow, and reflection processing with a more obvious light shadow. Scheme III is not very different from Scheme II. The sense of knowledge shadow is slightly weakened and the rendering time is longer. Scheme IV, Scheme V, and Scheme VI use the LuxRender rendering engine. According to the effects of D, E, and F in Figure 10, the indoor lighting effect of Scheme IV is very real. The indoor light processing and reflection processing are excellent. The details of light shadows and light levels are obvious, which is much less noisy than in Scheme I. The overall effect of Scheme V and Scheme VI is also improved compared with Scheme II and Scheme III, but the shadow degree is deeper and the rendering time is longer. The Octane rendering engine is used in Scheme VII, Scheme VIII, and Scheme IX. According to the analysis of G, H, and I effects in Figure 10, the rendering image in Scheme VII is generally clean, with less noise and good light rendering, but insufficient shadow details. It has a poor cloth material rendering effect. The shadow detail rendering of Scheme VIII is rougher and there is a certain gap with the real shadow effect. Because the Octane rendering engine is pure GPU rendering, rendering client III does not support this kind of lighting rendering, so Scheme IX's rendering effect is completely black. Comprehensively considering the rendering methods, time, and application scenes of the above nine rendering schemes, Scheme IV should be the best rendering scheme for scenes, lighting, textures, and materials.

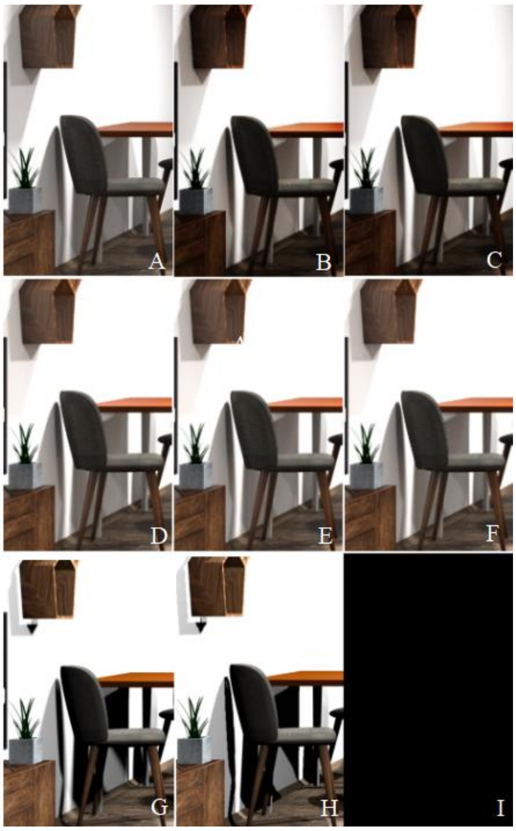

Figure 10. Comparison of nine different rendering scheme

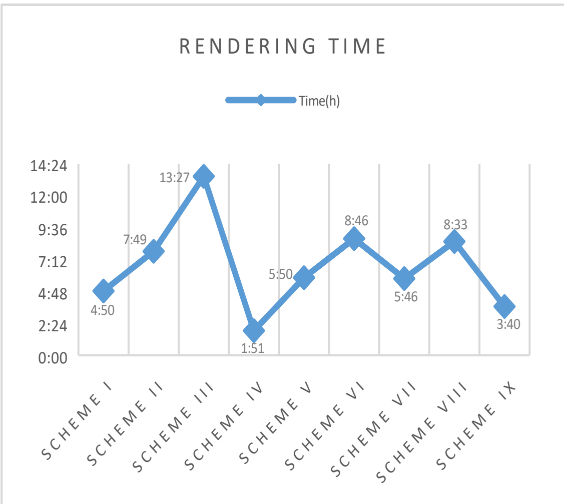

Figure 11. Rendering time of nine schemes

5 CONCLUSION

In the process of 3D rendering strategy design, it is necessary to comprehensively consider multiple factors and form the optimal rendering strategy through the comparative study of various methods. At present, the three constraints of 3D rendering strategies are rendering time, rendering effect, and rendering cost. This paper has designed and implemented a number of contrast experiments on the above three aspects to find efficient and high-quality 3D rendering strategies. In this paper, through the control variable method, the rendering method and hardware configuration are respectively controlled. Nine rendering methods are formed. For the same scene, the advantages and disadvantages of each method are pointed out through the analysis of the rendering effect, rendering time, and hardware. Multi-strategy 3D rendering effect research can provide some ideas and solutions for current 3D rendering, but at present, only three rendering clients and three rendering methods have been designed in the experiment. The experimental results obtained have certain limitations and the experimental effects still need to be improved in the future.

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