Fast Illumination Shading Method for Immediate Radiance Rendering

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ABSTRACT

High realistic rendering has been applied in many fields because it can generate realistic images. However, this kind of rendering needs a lot of computing resources, and it is difficult to achieve real-time speed, it is difficult to meet the needs of real-time application scenarios. Aiming at this problem, this paper proposes a rendering method suitable for real-time display. For the indirect light source coloring part, this paper proposes an image spatial region division to accelerate the rendering structure, which improves the rendering efficiency and avoids the problem caused by insufficient sampling points. Finally, this paper proposes a method based on ambient light shading to eliminate energy over transmission. This method mainly focuses on high-quality rendering under interactive conditions. It can realize scene roaming smoothly under the condition of conventional hardware, making the display object of complex 3D scene more realistic. The method of low-frequency global illumination energy block coloring is used to improve the rendering speed. Compared with the existing methods, our method achieves high realistic real-time rendering of complex models.

CCS CONCEPTS

• **Computing methodologies**; • **Computer graphics**; • **Rendering**;

KEYWORDS

Virtual light source, Fast rendering, Rendering of region, Immediate radiance rendering

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1 INTRODUCTION

The immediate radiance algorithm itself is a simplified version of Monte Carlo two-way path tracing [1]. Compared with the general path tracing, it adds some restrictions, but the algorithm can be fully integrated into the rendering pipeline. Different from the general path tracing, the path selection is simplified by the immediate radiance. The single-layer sampling path from the light is fixed by the current frame, through which all pixels calculate the indirect illumination value. Traditional path tracing generates these paths pixel by pixel. The biggest difference between the two is that the immediate radiance changes to reuse these paths pixel by pixel. The significance of the algorithm lies in its excellent efficiency. The immediate radiance algorithm used in this paper only provides one layer of indirect illumination effect, while the path tracing algorithm can transmit light energy iteratively in multiple layers. To produce this effect, we need a virtual medium to transmit energy indirectly. This medium itself is not a light source, but it has the property of light source, which can transfer energy to other triangular patches in the scene. This medium is called virtual point light source. The purpose of establishing the concept of virtual point light is to transform the original complex path transmission process into two steps: virtual point light sampling and virtual point light coloring. In this paper, for the indirect light source coloring part, the image space region division is proposed to accelerate the rendering structure, improve the rendering efficiency, and avoid the problem caused by insufficient sampling points. Finally, the method of eliminating energy over transmission based on ambient light shading is proposed. The existing realistic algorithm generally takes a few hours or days [1–4], relatively speaking, our method can achieve real-time.

2 RELATED WORKS

The typical global illumination algorithm is to obtain realistic rendering effect by simulating the transmission of light in the virtual scene. Therefore, it is necessary to model the light source of the real scene. At present, there are two most common light source modeling methods, one is to establish many virtual point light sources, and the other is the panoramic lighting image collected from the real scene. The research of global lighting technology mainly includes two directions. One method is the related algorithm using light as energy transmission medium. For example, path tracking algorithm or real-time radiation algorithm. The other is the global illumination theory based on patch as propagation medium, of which the most typical is the radiance algorithm.

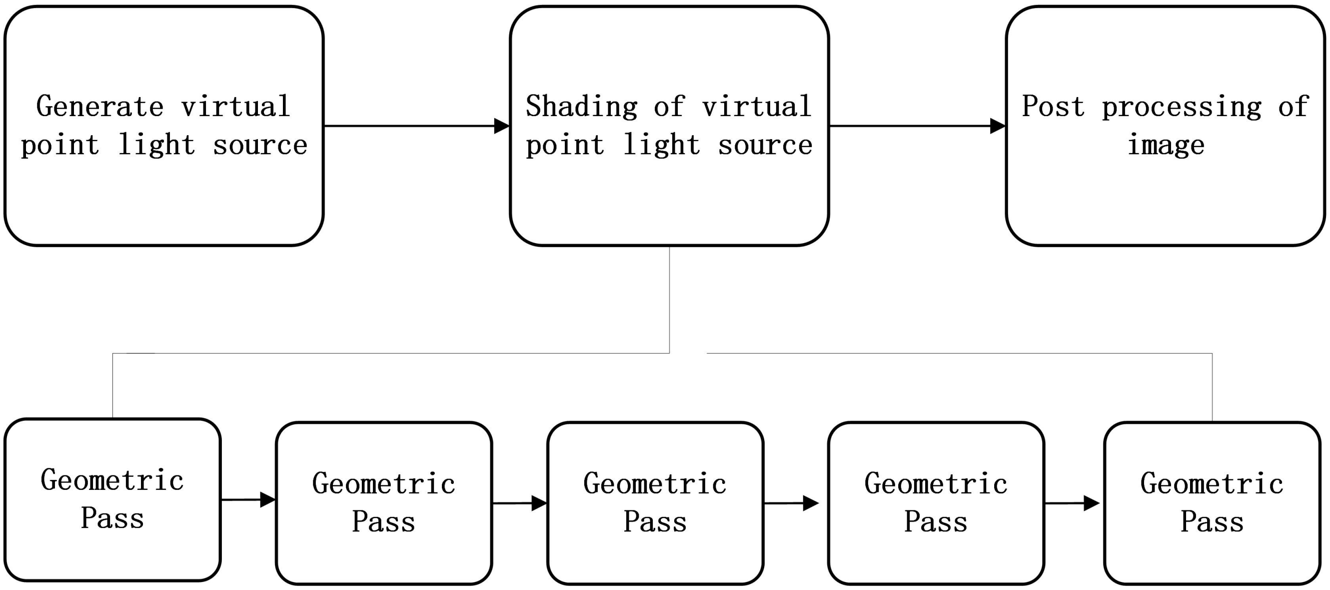

Figure 1: Flow Chart of Immediate Radiance Rendering.

Reference [1–3] introduces the drawing method of path tracking. The path tracking algorithm does not approach the physical meaning of global illumination, so it can calculate radiosity well. A real-time radiation algorithm is proposed for the first time in references [4–6]. Compared with the radiometric algorithm, the direct radiance algorithm does not need any pre calculation at all, and can deal with dynamic scenes and dynamic light sources. In fact, the physical principle of the algorithm is very different from that of the radiation algorithm. In references [7–9], ambient occlusion is used to achieve global illumination. In reference [7], a simple dynamic model can be processed by iterative approximation of ambient light masking technology. [10] Screen space based ambient light mask (SSAO). The RSM implementation of light source sampling is proposed in references [11–13] and subsequent improved versions. In reference [12], an important sampling method is proposed to simulate fuzzy reflective surface materials. In references [14–16], a new energy transmission algorithm is proposed, which transmits indirect light energy through a light propagator (VLP), which is stored in a four channel 3D texture according to the spherical harmonic function [17]. The above global illumination method still has some problems in rendering, such as slow speed and poor rendering effect.

3 OVERVIEW OF RENDERING PROCESS

Global illumination rendering based on real-time radiance can be divided into three steps: virtual point light generation, delayed rendering and post-processing. This section mainly introduces the macro framework implementation of algorithm optimization in the following sections.

The current immediate rendering methods are to set the number of light sources in the GPU hardware, while the graphics card generally supports 8 light sources. Therefore, there is a bottleneck in the number of light sources when using the existing GPU hardware for immediate radiance rendering. Although the above method can utilize the hardware of GPU to optimize the rendering process. Each light source needs to go through a rendering process, and the final result is obtained by superimposing these rendering effects, which leads to the strict limitation of the number of light sources in forward rendering technology. Therefore, the traditional rendering technology is difficult to render hundreds or even tens of thousands of virtual point light scenes.

In reference [13], a delayed rendering technology suitable for current hardware is proposed, which is suitable for real-time radiation rendering. This chapter mainly introduces its advantages and the process required to realize the technology, and makes necessary improvements and improvements.

As shown in Figure 1, compared with the general forward rendering technology, the rendering pipeline is transformed through shaders, the rendering process is divided, and the single frame rendering is completed through multiple processes. The specific process is as follows:

1) Discrete acquisition and modeling of virtual point light sources in different directions according to the real environment, that is, there is a spherical sky at the outermost edge of the scene, on which some discrete virtual point light sources are evenly distributed. The illumination information and intensity of the point light sources can be collected from the real environment or set by themselves.
2) Geometric pre rendering reduces the number of points or triangular patches that do not need to be drawn, outputs the final geometric pixel points that can affect the rendering effect (this point, as a geometric unit, contains useful information for rendering such as position and material), delays the light source shading process, and completely separates the influence of the light source in the geometric pre rendering stage. Enter model data in the scene and draw the scene.

Calculates position, normal, and material information pixel by pixel. This information is not output to the frame cache, and the intermediate results required for shading are stored in the geometry cache of the multi render target.

3) The lighting shading process of the core divides the shading stage into two steps. First, the geometric section is calculated and drawn, and then the block is divided and colored. Before preprocessing the results using a multi-pixel light source. Input the point light source and parallel light sequence, and calculate the light energy value pixel by pixel. This lighting shading process is no longer to shade the triangular patches of the scene, but to shade the data in the previous geometry cache, eliminate a large number of invisible points, reduce the dimension of three-dimensional space to two-dimensional space, and completely solve the problem of multi light efficiency. This is the result of step 2 above. This step is mainly responsible for processing how to convert the geometric pixels output in the previous step (each point corresponds to the pixels of the image to be output in the future). For each geometric pixel, the existing rendering method should be used to calculate the final effect image. At this time, all virtual point light sources have been considered. The rendering result can be obtained by multiplying the lightmap and diffuse map pixel by pixel. Finally, the rendering results are processed and displayed.

As shown in Figure 1, the results of each process in the delayed rendering phase are shown. From these decomposition diagrams, we can also find that most operations after geometry transfer are based on image space. In the schematic diagram, the rendering effect is mainly to delay the display of the rendering effect. 100 dynamic rotating spotlight scenes are realized, and the rendering effect can be stable at 50 frames.

The framework has the following advantages for real-time radiation rendering

1) Under the condition of keeping the rendering speed unchanged, the complexity of rendering is reduced and the rendering speed is improved. The rendering complexity of forward rendering technology depends on the complexity of the model multiplied by the number of light sources. Our method divides the rendering step into the rendering complexity of the geometric model plus the number of light sources in the fixed resolution image. Scene complexity is completely independent of lighting complexity, and there is no need to deal with the constraint relationship between light source and geometry. It also avoids the need to provide additional channels for independent processing after the model receives light, and avoids a large number of calls.
2) The light source is separated from the material properties. Model materials are no longer affected by light sources, and adding new types of light sources does not affect material shaders. The functional modules are more specific, and the codes of the two functional modules are not mixed. Pixel shaders are too large due to the diversity of lighting and materials. This decoupling operation can minimize the hardware cost.

3.1 Fast Coloring Method of Virtual Point Light Source

In order to get high realistic rendering results, we use the following rendering formula.

$$E_p(x,n) = \Phi \frac{max\{0,\ dot(n_p, x - x_p)\}\max\{0,\ dot(n, x_p - x)\}}{\left\|x - x_p\right\|^4} \quad (1)$$

where Ep is the energy that a virtual point light source currently sampled can finally transfer to the corresponding position of the pixel, n, x is the normal and position information of the virtual point light source, Φ is the reflected luminous flux. The information needed to calculate the transfer energy is stored in the three g-buffers generated before. Every pixel in g-buffer can be regarded as a virtual point light source. As long as the size of shadow map is set, a large number of virtual point lights can be generated effectively. At the same time, for the spotlight model, it can be successfully simulated by multiple importance sampling of the current pixel cluster.

Formula 1 is the light energy transmission formula of the virtual point light source, which represents the normal value of the geometric position corresponding to the pixel and the virtual point light source respectively, and represents the geometric position corresponding to the pixel and the virtual point light source position respectively. It means that the energy obtained is inversely proportional to the square of the distance between the two positions. The farther the distance is, the less energy is obtained. In this section, the formula is used to shade the virtual point light source. There are two main problems in the coloring stage. Aiming at the realistic rendering, a coloring scheme suitable for low-frequency signals is proposed, which also improves the rendering efficiency. In the coloring formula, the energy is inversely proportional to the distance, which leads to energy over.

3.1.1 A.Block Coloring Method for Regional Division. The conventional forward rendering mode is not feasible to process hundreds of virtual point lights in a single frame, because each light source needs a pass, each pass needs to draw the scene once, and finally superimposes the rendering results. It is unacceptable to process hundreds of passes in a single frame. Facing such a problem, we must introduce the delay rendering technology. This technology delays the shading stage, reduces the dimension of shading processing, and enables hundreds of light sources to render in real time. However, due to the large number of virtual point lights, it is difficult to deal with them efficiently even by means of delayed rendering. It is still necessary to design and optimize the lighting shading stage.

Most of the indirect illumination is low-frequency signal, so the indirect light energy received by adjacent pixels is close. According to the above inference, we do not need to use so many virtual point lights to render all the rendered pixels. Only the pixels with obvious geometric discontinuity around the pixel need to be recalculated. The geometrically continuous region can be directly used to all pixels in the region through one calculation. Although this approximation is still lack of physical basis, but the effect is excellent, not only greatly reduce the cost of lighting shading, but also improve the rendering effect. Because the global illumination algorithm is simulated based on sampling, the sampling node can only represent part of the energy transfer path. Because part of the energy transfer is blocked, there will be obvious color difference between the adjacent pixels in geometric position. However, through this approximation, the visual experience can be significantly improved and the unreasonable color difference can be eliminated.

We can get the g-buffer of the viewpoint, including pixel by pixel normals and position information, through the geometric rendering phase of delayed rendering. We can use this information and use edge AA [9] to determine whether adjacent pixels have geometric continuity, and calculate the weight value pixel by pixel using the depth and normal deviation from the surrounding pixels.

The obtained results can not only be used for the condition of global illumination region division, but also make up for the relatively weak anti aliasing function of delayed rendering. The final color of pixels is obtained by interpolation between the current pixel color and the adjacent pixel color with weight value. the brighter pixels in the figure indicate that there are geometric jumps around the pixels. These bright pixels outline the boundaries of the model after rendering, and the brightness of the display is proportional to the geometric jump.

Firstly, some weight information with no obvious geometric change is filtered out by threshold, which shows the mapping position offset of adjacent pixels on the same plane. The current pixel and the adjacent pixel receive very close low-frequency global light energy, so these weight values should not be retained to the cumulative difference division stage. It is ensured that all the accumulated points have obvious geometric differences in the process of regional division. As shown in Figure 1, the white parts in the figure are obvious geometric sections filtered by threshold.

3.1.2 B. Eliminating Energy over Transmission based on Ambient Light Shading.

Virtual point light source is not the traditional point light source, so the energy transmission mode can not be completely in accordance with the traditional energy transmission mode. However, the virtual point source should not have the problem of energy over transmission. The essential physical meaning of virtual point light source is energy transmission medium, not real light source. Through the formula of 2, we can know that when the position of the virtual point light source is very close to the corresponding geometric position of the pixel, and the position line is close to each other's normal, the bright spot will appear. This situation usually occurs at the corner of the model, which belongs to the shadow corner. Unfortunately, the sampling point is just at this position, and there may be bright spots when the viewpoint looks at the corner. This rendering result is obviously different from the normal visual experience. The conventional limitation is to take the threshold when the distance between two points is less than the threshold value, which can alleviate some over bright spot problems. However, some of the shadow areas are still bright. It can be concluded from the illumination equation that these points are at the corner of the model, and the bright spot has obvious geometric properties. According to this geometric property, we can use ambient shading technology to reduce the brightness of the corner, and finally make the rendering result without occasional bright spots.

The general ambient light masking technology [12] is not suitable for the current rendering process. The ambient light shading determines the ratio of light energy that can be received based on the occlusion relationship of the geometric model around the visible point. In formula 3, the geometric shadowing relationship of all directions in the hemisphere with the visible point as the center is integrated. This geometric occlusion relationship is related to the normal of the visible point. The closer to the normal, the greater the occlusion weight. Whether it is occluded or not. The integral result is the obscured value, but the integral is not a computer recognized calculation mode. Therefore, it is necessary to discretize the shadowing relation of a finite number of random rays to approximate the shadowing rate. However, a large number of detection rays emitted from visible points must rely on traditional ray tracing, which cannot be simulated by rendering rays. Therefore, the traditional ambient light masking costs too much, and the algorithm needs to be approximated.

$$\mathrm{A}\,(p,n) = \frac{1}{\pi} \int V\,(\omega,p) * \max(\omega \cdot n, 0)\; d\omega \tag{2}$$

The simulation can be approximated here, because geometric information is carried pixel by pixel in the geometric pass phase. The detection light selection can judge the occlusion relationship based on the surrounding pixels. Different from the ordinary ambient light masking technology, the occlusion ratio is no longer calculated here, but the distance from the surrounding pixel occlusion point to the current pixel and the occlusion degree [8]. The inference here is based on non physics and is obtained by observation. The farther the distance between the surrounding pixels is, the smaller the degree of occlusion is. The geometric position of the surrounding pixels is very close to the current pixel and tends to the corresponding normal value of the current pixel, which indicates that the occlusion rate is large. In formula 2, X is the influence factor that can be set according to the current scene and represents the distance. The general representation is an empirical formula of occlusion based on observation. All sampling paths are based on the geometric information of the surrounding pixel values. Finally, the shadowing relation of the final visible point is obtained by averaging the results. This kind of approximation can ensure good output in most cases, but the occlusion judgment of some pixels is not ideal, so it can be blurred after obtaining the complete occlusion image. The occlusion blur algorithm needs to consider the geometric boundary problem, so it needs to use bilateral blur [11].

$$A(p,n) = \frac{\sum_{\mu} max((p_n - p)\,n, o) * \frac{1}{(1+\|p-p_n\|^{x})}}{\mu} \tag{3}$$

The overshadowing value can well limit the problem of energy over transmission in the immediate radiance. According to the conditions of inherent geometric attributes generated by the transmission point, the properties of the geometric attributes are obtained and the brightness of corresponding positions is reduced.

4 EXPERIMENTAL RESULTS AND ANALYSIS

First of all, in order to show that the buffer pool gain RSM (Reflective Shadow Maps) can guarantee the rendering fidelity and improve the rendering efficiency. By testing the time required for

Table 1: Comparison of Indirect Illumination Efficiency with Shadow Map

Test model	Direct lighting (ms)	FPS	
		Calculating SM	buffer pool gain RSM
Cave	2.9	9.1	50.1
		4.1	10.6
Building	8.5	2.6	40.7
		0.55	28.2

Table 2: Comparison of Indirect Illumination Efficiency with Shadow Map

Test model	Number of virtual light	Global lighting (ms)	
		Calculating SM	buffer pool gain RSM
Cave	256	5.3	1
	512	40.2	1.2
Building	256	60.3	1.3
	512	110.2	2.0

Figure 2: Final Effect of Immediate Radiance.

indirect lighting generation and the overall frame rate of rendering in various scenes under complex moving conditions, the method is compared with the traditional RSM which generates shadow map frame by frame. 256 or 512 virtual point light sources were used to test. As shown in Table 1 and 2, the test results show that the method greatly reduces the consumption of single frame sampling and significantly improves the frame rate. Compared with the direct light consumption, the indirect light sampling part also shows acceptable consumption value. By comparison, RSM technology based on buffer pool gain makes use of the correlation between light source frames to reduce the generation of a large number of shadow maps and improve the operation efficiency.

The block coloring technology is tested. Through Figure 2, it fully shows that the partition region coloring technology can not only improve the rendering efficiency, but also improve the rendering realism. The left picture is the color rendering of region division, and the right is the effect picture of unused region division. The red box indicates the main difference between the two figures. It can be seen that due to the limited sampling light source in the right picture, obvious light energy level crossing occurs at the junction between the occluded and unshielded virtual point light source, resulting in energy fault of geometric continuous points. Through the previous region division technology can well solve a large number of such problems, before the average block energy, so the rendering effect is more smooth.

Through the shading test of 158 scenes, the pixel by pixel virtual point light shading and area virtual point light shading are compared. As shown in Table 2, the latter has better rendering efficiency. At the same time, compared with the coloring module, the consumption of the new area division module can be ignored. The region division shading scheme can accelerate the rendering at all resolutions.

Finally, taking the application scene as the experimental object, the effect of only using direct lighting is compared with the effect after using the method in this paper. The shadow area is completely dark. After indirect lighting rendering, the shadow area is no longer abrupt and soft to be illuminated. The original illuminated position rendering results are more close to the ideal visual experience. When the image is enlarged, it can be seen that the indirect light energy is not fixed, and the side surface of the inner concave body is obviously darker than that of the outer concave body, which conforms to the principle of light energy transmission. At the same time, the indirect energy of the inner concave body also has obvious light and dark difference due to the angle problem. This change of shadow area can not be obtained by setting the ambient light parameters uniformly. Setting the ambient light is obviously more unified and completely intervened by human beings. Moreover, the effect has no physical significance, just to make the shadow area visible. Moreover, the system does not need manual intervention. The illumination has physical significance, and the effect is more ideal, tends to be real, with geometric personalization and light source correlation.

5 CONCLUSIONS

Aiming at the problem of virtual point light shading, this paper proposes a region division coloring method, which not only avoids the performance bottleneck, but also effectively improves the rendering realism. The phenomenon of energy over transmission is corrected by using ambient light masking technology. Experimental results show that the virtual point light shading method can achieve high realistic rendering effect. In the future, our method will be combined with deep neural network to further improve the rendering speed.

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