RSM Virtual Point Light Sampling Algorithm Based on Buffer Pool Gain

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ABSTRACT

The immediate radiance depends on a large number of virtual point light sources as the medium of single indirect illumination, so the rapid and effective generation of a large number of virtual point light sources is the problem that the algorithm must face. The highlight on the desktop is random sampling of virtual point light sources, which do not exist and are only used as the medium of energy transfer. Here is a schematic effect, so all the virtual point lights are drawn. It can be seen that the number of virtual point lights is very large, and the distribution is random. At the same time, the light red on the desktop comes from the virtual point light sampled from Stanford dragon. Due to the strict requirements for the restoration of the real color in the rendering of cultural relics, there is a color deviation problem in the transmission of virtual point light source energy through the above completely non physical means, so it does not meet the demand of high fidelity. In this paper, a new virtual point light sampling method is established, which can effectively obtain the shadow map of the sampled virtual point light source. Under the condition of ensuring frame rate, the correctness of light energy transmission is guaranteed to the greatest extent. At the same time, it can inherit the advantages of the original RSM (Reflective Shadow Maps).

CCS CONCEPTS

• **Computing methodologies**; • **Computer graphics**; • **Shape modeling**;

KEYWORDS

Virtual light source, Fast rendering, Sampling method, Buffer pool gain

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1 INTRODUCTION

In recent years, 3D virtual display [1] is an important part of the digitization of cultural relics, rendering technology is to reproduce the original appearance of cultural relics model. The simple rendering technology can't simulate the process of light energy transmission in the environment, which leads to the rendering results far from the actual cultural relics. The accurate and real restoration of 3D model data of cultural relics needs global illumination rendering technology. This technology can make up for the missing energy transfer [2, 3] between the surfaces of cultural relics in conventional rendering technology and accurately restore the light energy obtained by cultural relics under specific lighting conditions. Although the global illumination technology has a good effect, the current global illumination [4–6] technology has the following bottlenecks:

- For real-time problems, the global illumination algorithm needs to calculate a large amount of indirect energy transfer, which increases the computational complexity exponentially compared with direct illumination. This computational complexity leads to the speed problem of the global illumination algorithm. Mainly reflected in the rendering frame rate is low or completely unable to run in real-time.
- The problem of realism includes the tradeoff between speed and hardware requirements [7–9] and whether the rendering effect can be adjusted according to the hardware conditions. How to make up for the rendering effect under the condition of insufficient sampling rate and improve the rendering realism of the algorithm itself is an important issue.

The immediate radiance algorithm used in this paper only provides one layer of indirect illumination effect, while path tracking can transmit light energy iteratively in multiple layers. Immediate radiance to produce this effect requires a virtual medium to transfer energy indirectly [10, 11]. The medium itself is not a light source, but it has the nature of light source, which can transfer energy to other triangles in the scene. This medium is called virtual point light source.

There is a bottleneck in the application of forward shading in the field of global illumination with immediate radiance. Although GPU hardware optimizes the rendering process a lot. However, each light source needs to pass through a rendering pass, and the final result is obtained by superposition of these rendering effects, which results in the very strict limitation of the number of light sources in forward rendering technology. Therefore, the scene with hundreds of virtual point lights is difficult to render by conventional rendering technology [12, 13].

The immediate radiance depends on a large number of virtual point light sources as the medium of single indirect illumination, so the rapid and effective generation of a large number of virtual point light sources is the problem that the algorithm must face. The highlight on the desktop is random sampling of virtual point light sources, which do not exist and are only used as the medium of energy transfer. Here is a schematic effect, so all the virtual point lights are drawn. It can be seen that the number of virtual point lights is very large, and the distribution is random. At the same time, it can be seen light red on the desktop, which comes from the virtual point light sampled from Stanford dragon. Due to the strict requirements for the restoration of the real color in the rendering of cultural relics, there is a color deviation problem in the transmission of virtual point light source energy through the above completely non physical means, so it does not meet the demand of high fidelity. In this paper, a new virtual point light sampling method is established, which can effectively obtain the shadow map of the sampled virtual point light source. Under the condition of ensuring frame rate, the correctness of light energy transmission is guaranteed to the greatest extent. At the same time, it can inherit the advantages of the original RSM.

2 RELATED WORKS

CPU (center processing unit) is the main execution hardware of current applications, which is suitable for dealing with complex things. However, due to the hardware architecture, it is not ideal in the field of floating-point computing and highly parallel data processing. GPU (graphics processing unit) hardware is just suitable for these tasks, so GPU hardware is gradually taking over these difficult parallel tasks. Due to the working nature of CPU and GPU, their hardware architectures are quite different. CPU hardware uses complex control unit and cache and other devices to continuously improve the execution efficiency of a single core unit. GPU hardware is mainly used for graphics rendering, which requires a large number of parallel units to ensure the execution efficiency. Therefore, GPU obtains faster running speed by accumulating more computing cores. But even if the GPU hardware is suitable for some program architectures, due to the lack of good programming environment and the lack of linkage ability with CPU, it can not run smoothly on GPU. In order to be better used in the field of general computing programming, CUDA and other related technologies were born. CUDA can use C language as the development environment, without graphics API. At the same time, it has the ability of GPU and CPU to cooperate with each other. GPU can be used as a coprocessor to help CPU complete a large number of operations under the condition of parallel demand [1-6].

In NVIDIA hardware, streaming process is the bottom processing unit in GPU. A large number of streaming processes are integrated in a single GPU, and these processing units can operate in parallel. The streaming multiprocessor consists of several basic processing units, a small number of storage units and instruction units. The streaming multiprocessor also forms the texture processor cluster. This hardware architecture is completely transparent to CUDA (Compute Unified Device Architecture) and is mainly used for hardware architecture in the rendering pipeline. The combination of these processing units eventually forms the processing cluster of GPU [2-12].

CUDA also needs to compile code before running. Different from the traditional compilation mode, CUDA will process host and device separately. Host module compilation mode is similar to traditional C language. But the device part is compiled by NVIDIA special compiler, and finally compiled into parallel thread execution, which is handed over to GPU for processing.

Although GPU has excellent parallel computing capability, it also has the following problems: 1) The core of GPU does not have a cache hardware structure like CPU to reduce the access times of main memory. The delay of accessing storage unit is large, so it is necessary to reduce this kind of access as much as possible. There are also many kinds of GPU memory. All blocks share the global storage unit, which is very slow to access. In the streaming multiprocessor hardware unit, there is a local shared memory space, which is nearly 100 times faster than the global memory space. This memory unit has the fastest access to registers in each thread. How to effectively use the limited resources is the GPU Programming must pay attention to. 2) The CPU has a branch prediction mechanism, which can effectively avoid the problem of branch efficiency. But GPU does not have such hardware, so branch instructions need to be minimized. How to avoid the performance problems caused by these hardware becomes the focus of CUDA Programming. At the same time, the hardware delay can be ignored by improving the parallelism and making full use of the advantages of hardware.

3 RSM VIRTUAL POINT LIGHT SAMPLING ALGORITHM BASED ON BUFFER POOL GAIN

Compared with the general forward rendering technology, the rendering pipeline is transformed through the shader, the rendering process is split, and the single frame rendering is completed through multiple passes. The specific process is as follows:

Virtual point light sampling phase. 2) Geometric pass delay the process of light source coloring, completely separate the influence of light source in the geometric rendering phase. Input the model data in the scene and draw the scene. The position, normals are calculated pixel by pixel, and material information. This information is not output to the frame cache, and the intermediate results needed for shading are stored in the geometry cache of the multi render target. 3) Lighting coloring pass, the coloring stage is divided into two steps, first to find the drawing geometry section, and then block division coloring, the process will be described. Before using a multi-pixel light source to preprocess the results. Input the point light source and directional light sequence, calculate the light energy value one by one pixel. This lighting coloring process is no longer to color the triangular patches of the scene, but to color the data in the previous geometry cache, eliminate a large number of invisible points, and reduce the dimension of 3D space to 2D space, which completely solves the problem of multi-light efficiency. 4) The rendering results can be obtained by multiplying lightmap and diffuse map pixel by pixel. Finally, the rendering results are processed and displayed. The flow chart is shown in the Figure 1

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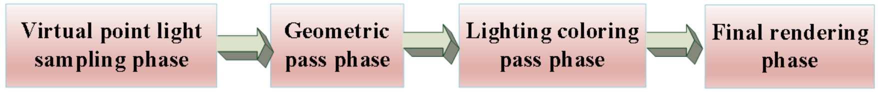

Figure 1: The Flow Chart Virtual Point Light Sampling and Rendering.

Figure 2: Final Effect of Virtual Point Light Source.

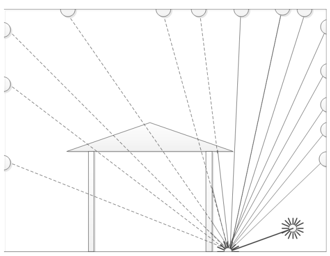

Figure 3: Sketch Map of Physical Meaning of Shadow Map.

shown in Figure 2, the highlight on the desktop is random sampling of virtual point light sources, which do not exist and are only used as the medium of energy transfer. Here is a schematic effect, so all the virtual point lights are drawn. It can be seen that the number of virtual point lights is very large, and the distribution is random. At the same time, it can be seen light red on the desktop, which comes from the virtual point light sampled from Stanford dragon.

In reference [13], the method of reflective shadow maps was used to generate virtual point light source. Reflective shadow maps is a kind of main light source to generate special shadow maps. The algorithm improves the sampling efficiency of virtual point light source. However, a large number of virtual point lights are sampled in each frame, and there is no inter frame correlation between virtual light sources. It is unrealistic to generate shadow maps of all virtual point light sources frame by frame. Because the influence of single virtual point light source is relatively weak compared with direct illumination, the shadow map of all virtual point light sources is ignored by non physical approximation, that is, the virtual point light source ignores the energy emitted by the scene model.

This sampling strategy is suitable for fully dynamic scenes and light sources. However, in order to achieve efficient sampling, its physical significance is ignored. Although a single virtual point light has little effect on the whole scene rendering scene, the cumulative effect cannot be underestimated. This kind of over painting can cause the rendering scene to be too bright and color biased.

As shown in Figure 3, a sketch of the impact of a virtual point light generated by a light source on the scene. The straight line part indicates that the virtual point light source can indeed transmit energy, and the dotted line part is obviously blocked. However, in the rendering process without shadow map, the dashed part will still become the energy transfer path. This is the proof of the necessity of introducing this algorithm in this section, otherwise a large number of occlusion paths can still transmit energy, which obviously violates the physical phenomenon. In this section, a new sampling algorithm is proposed to correct the accuracy of energy transmission.

Due to the strict requirements for the restoration of the real color in the rendering of cultural relics, there is a color deviation problem in the transmission of virtual point light source energy through the above completely non physical means, so it does not meet the demand of high fidelity. In this paper, a new virtual point light sampling method is established, which can effectively obtain the shadow map of the sampled virtual point light source. Under the condition of ensuring frame rate, the correctness of light energy transmission is guaranteed to the greatest extent. At the same time, it can inherit the advantages of the original RSM.

This section will describe the RSM virtual point light sampling method based on buffer pool gain through two stages. A large number of inter independent virtual point light sources are selected through the initial sampling, and then the inter frame correlation of virtual point light sources is established based on the buffer pool through the second stage sampling selection.

The main objective of this section is to obtain a large number of available virtual point lights, but the sampling results are not filtered.

This kind of special shadow maps still uses the light source as the viewpoint for rendering, but it not only obtains a mapping map with depth information. In order to calculate the energy value emitted by the virtual point light source in the fixed direction, additional buffer is needed to record the normal value, coordinate value and reflected luminous flux of the surface [13]. At the same time, this special shadow map can still be used to calculate the shadow area of the main light source. Conventional rendering with shadow requirements also needs this rendering process. Therefore, more buffers are needed to store additional information, that is, additional light source space g-buffer is required.

As shown in Figure 4, depth information can be used to deduce the location information of pixels, but in order to achieve faster execution speed, some space is sacrificed to ensure that all required data can be accessed immediately.

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

Figure 4: Final Effect of Different Light.

Formula 1 is the energy that a virtual point light source can finally transmit to the corresponding position of the pixel. , are the normal and position information of virtual point light source, namely reflected luminous flux. The information needed to calculate the energy transfer exists in the three g-buffers generated before. The position of each pixel in g-buffer can be regarded as a virtual point light source. As long as the shadow map size is set, a large number of virtual point lights can be generated effectively. At the same time, for the spotlight light source model, the current pixel cluster can be simulated by multiple importance sampling.

Through this special shadow mapping process, a large number of virtual point lights can be sampled. Each geometry cache data has stored any information needed for the energy transfer of virtual point light source. The data stored in the pixel can be used to simulate the virtual point light in the scene. At this time, we will introduce how to select the new sampling points and how to reduce the virtual sampling points by selecting the new sampling points.

This section is devoted to solve the problem that all shadow maps of virtual point light cannot be generated. A reusable strategy is proposed to obtain the sampling strategy of virtual point light with shadow map.

The resampling selection method of virtual point light based on buffer pool gain is a virtual point light incremental creation algorithm. By using inter frame correlation to increase reusable virtual point lights, the cache pool will save these virtual point lights which are still available, and only need to create shadow mapping for the newly added virtual point lights. Due to the limited number of newly added virtual point lights, it can be created in real time.

This incremental creation algorithm is based on the correlation between light frames, so the influence of light motion state on the method is analyzed first.When the light source does not move, there is no need to generate a large number of virtual point light sources randomly. Using the virtual light source generated before can not only avoid the slight jitter of image rendering results caused by sample point transformation.

When the light source moves, because the movement is generally frame dependent, the virtual point light still illuminated can be retained. Therefore, it is necessary to determine whether the path from the previously generated virtual point light source to the current light source position is blocked by other triangular patches.

A pre-processing stage is added before the rendering phase. All pixels in the initial sampling of the light source position in the first frame generate their own shadow maps. The preprocessing results are stored in the virtual point light cache pool, and then deleted and added frame by frame. All virtual point lights in the buffer pool have independent shadow maps. Then the buffer pool gain algorithm flow in the running phase is entered.

Among them, the energy update module needs to be updated for all the nodes that are still valid, because the movement of the light source will lead to the energy change of these virtual point lights. Although the left triangle patch is still available, the relative position with the light source has changed, and the corresponding RSM sampling pixel position has also been offset, so the information must be updated. The purpose of reusing the virtual point light is to avoid the steps of shadow mapping for the virtual point light source.

This algorithm has the following advantages: when fewer virtual point lights are created frame by frame, shadow can be created for each virtual point light Map, which can be used to judge whether a certain position can be illuminated by the virtual point light source in the delay stage. If the virtual point light source is not added incrementally, each virtual point light source must go through a rendering pass to create a shadow map, which can not run hundreds of passes in a single frame, so the conventional method can not be applied to real-time rendering. But this incremental algorithm can create a separate shadow map for each virtual point light source.

4 EXPERIMENTAL RESULTS AND ANALYSIS

In order to deal with the robustness of various scenes, we still use the RSM algorithm which ignores the occlusion relationship for the sampling points not in the buffer pool, which ensures the global illumination effect. Without using the current improvement, in extreme cases, the rendering results degenerate to the loss of global illumination. The improved RSM method can optimize the effect of extreme cases, and the worst rendering effect is more and more similar to the conventional RSM method. This is obviously a more desirable result. Under the condition of ensuring the frame rate of rendering, the accuracy of rendering can be ensured to the greatest extent. Unlike the traditional RSM method, the approximation deviation is not corrected. The results are shown in Table 1 and Table 2

Finally, a fast virtual point light sampling scheme based on physics is formed, which is suitable for all kinds of light source moving environment. It gets rid of the limitation of ray tracing sampling mode to the scene, and all operations are based on hardware accelerated rendering pipeline, which ensures the efficiency and maximizes the guarantee that the sampling results can be rendered based on physics.

This visibility determines the reusability of virtual point light, which will affect the fairness of random sampling, so we need to make the sampling distribution more reasonable. To ensure the rationality of sampling and the efficiency of rendering, the threshold of deleting and adding virtual point light is set. The virtual point

Table 1: Comparison Chart of Technical Efficiency of Regional Coloring (MS)

	Rendering of virtual light based on pixels	Rendering of virtual light based on regions	
		Region division	Region rendering
800*600	10.0	0.2	6.2
1024*768	18.1	0.7	11.8
1920*1080	43.5	3.6	20.6

Table 2: Comparison of Indirect Illumination Efficiency with Shadow Map

Test model	Direct lighting (ms)	FPS	
		Calculating SM	buffer pool gain RSM
Car1	0.5	10.1	72.1
		4.1	6.3
Car2	2.0	0.4	22.7
		0.22	15.2

light above the lower threshold must be deleted in each frame, and a new virtual point light must be generated to ensure the rationality. When a large number of virtual point lights are deleted, only the maximum number of virtual point lights is generated to ensure the rendering efficiency. According to the visibility principle, the currently occluded virtual point lights must be removed. If the number of removed virtual point lights is less than the lower threshold, the virtual point lights that have used more frames must be deleted. The virtual point lights are filtered according to the number of resident frames until the number of removed virtual point lights reaches the lower threshold. This ensures that new virtual point lights will be generated in each frame to replace the old ones and ensures the relative fairness of sampling. At the same time, when a large number of virtual point light sources are blocked, such as the sudden change of light source illumination, the global illumination quality is temporarily reduced to ensure the frame rate. The floating virtual point light storage pool will gradually fill the buffer pool after several frames. At the same time, the global illumination is generally a low-frequency signal, so this decline in quality will not significantly affect the rendering effect. At the same time, after several frames. It is possible to make up the virtual point light. The lower threshold mainly ensures the rationality of sampling, while the upper threshold focuses on the smoothing of rendering frame rate.

5 CONCLUSIONS

Due to the strict requirements for the restoration of the real color in the rendering of cultural relics, there is a color deviation problem in the transmission of virtual point light source energy through the above completely non physical means, so it does not meet the demand of high fidelity. In this paper, a new virtual point light sampling method is established, which can effectively obtain the shadow map of the sampled virtual point light source.The sampling method of RSM virtual point light based on buffer pool gain mainly includes: selecting a large number of inter-frame irrelevant virtual point light through the initial sampling and then establishing the inter-frame correlation of virtual point light based on buffer pool through the second stage sampling. In this paper, a new sampling method of virtual point light is established, which can effectively obtain the shadow map of the sampled virtual point light.

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