Real-time Rendering of Dynamic Clouds

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1 Introduction

This paper presents a fast cloud rendering method for dynamic scenes, where cloud shapes and lighting environments dynamically change. Although Harris' method [1] has been widely used in static cloud rendering, it can be fatally slow for real-time applications when, for example, light directions change. By introducing a 3D texture and re-arranging the algorithm, we realized 10-100 times faster rendering of dynamic clouds. The image quality was also improved by the finer representation of light distribution.

2 Harris method

In the Harris method, the density distribution of a cloud is modeled by a set of particles, each of which represents a Gaussian density distribution, processed as a textured polygon in GPUs.

The method consists of a pre-process and a rendering process. The pre-process calculates the intensity distribution of the direct light and the rendering process generates cloud images, referring to the intensity distribution obtained in the pre-process.

In the pre-process, the particles of clouds are first sorted along the light direction. Then, in the near-to-far order, the light intensity distribution is calculated by drawing a particle as a textured polygon onto the frame buffer with alpha blending. Since the buffer is overwritten when other particles overlap, it is read back to the CPU every time when drawn and the value at the center of particle is stored in the main memory, which is referred to in the rendering process. Because read-back is very slow, this data transfer is the bottleneck in the entire process. The sorting process also decelerates the execution. Moreover, since only one value is stored per particle, intensity gradation within particle is neglected, making the appearance of a cloud flat.

The rendering process is conducted in a similar way but without read-back, and is much faster than the pre-process.

3 Proposed method

In the proposed method, we introduced a 3D texture to avoid read-back. To avoid sorting process, we calculate 'attenuation ratio distribution', instead of light intensity itself. Let us consider the example shown in Figure 1. Point x1 is within the "shadow polygon" of particle 1, and the intensity is G1*I0, where G1 indicates the transmittance of the particle. Point x2 is in the shadow polygon of both particle 1 and 2, the intensity there is (G1*G2)*I0. Note that this is a simple scalar product and the particle processing order is arbitrary.

This computation can be performed in the following way: for each particle, calculate the shadow polygon, and render it to the 3D texture with the transmittance value of the particle. As mentioned before, the results do not depend on the particle order, and hence, sorting is not required. The resulting 3D texture is the intensity distribution itself, which can be directly referred to in the rendering process. Therefore, read-back is also unnecessary. Due to current GPU specs, multiplicative blending onto a frame buffer is performed by additive one in log-scale.

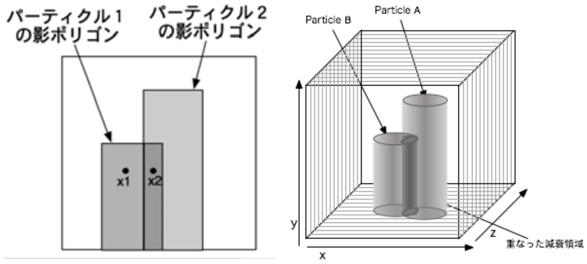

Figure 1: 3D texture representation of attenuation ratios.

4 Experiments

	9382 particles	32914 particles	60134 particles
Harris method	0.721 sec	3.164 sec	5.934 sec
Proposed (384^3)	0.038	0.154	0.161
(128^3)	0.007	0.015	0.016

Table 1: Comparison on CPU time. (voxel resolution).

On a PC with Geforce8800GTX, Intel Core 2 Duo1.83GHz, the processing time required in the pre-process was measured. Table 1 shows the comparison between the original Harris method and the proposed method. As shown in the table, the improvement in speed was significant: the proposed method was more than 10-100 times faster than the previous method. Figure 2 demonstrates improvements on image quality. Although the previous method failed to capture the detailed features of the clouds, the proposed method successfully generates delicate gradation inside a cloud.

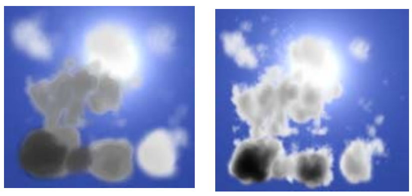
Figure 2 previous method proposed method

5 Conclusions

This paper presented a fast rendering methods of dynamic clouds. Significant improvements over the Harris method were made by utilizing a 3D texture, resolving the bottleneck caused by GPU-CPU read-back. The proposed method allows real-time rendering of dynamic scenes with moving clouds and light sources. The image quality was also improved by the finer representation of light distribution.

References

Harris, M. J. and A. Lastra, Real-Time Cloud Rendering. Computer Graphics Forum (Eurographics 2001 Proceedings), 20(3):76-84, September 2001.