GPU based on-the-fly light emission-absorption approximation for direct multi-volume rendering

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Abstract

We present a novel on-the-fly scatter approximation scheme that can be applied concurrently to multiple volumetric datasets. We use a simplified version of the emission-absorption model, including single scattering and shadowing and guide the scatter sample positions and in-scatter coefficients by local gradients. This allows us to render multiple intersecting volumes with our rendering system with clearly visible improvements in rendering quality over local illumination models, while maintaining interactive frame-rates.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation—Display algorithms

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Introduction While local illumination models, such as the Phong model, can be considered the standard approach for Direct Volume Rendering (DVR), many researchers have shown that global illumination approximations are better suited to emphasize three-dimensional structural arrangements. However, global illumination based on an emission-absorption model is not commonly used in DVR systems, because of its extreme computational cost, which makes its application difficult under hard real-time constraints. Besides, the use of these models for scenes, containing more than one volume at once, has not been investigated at all. On the one hand because of the lack of stable DVR systems, which support the traversal of more than one volume dataset at a time, and on the other hand, because of the already computationally demanding evaluation of multiple intersecting volumes.

Influenced by the visually appealing results of the algorithms proposed by Ropinski et al. [RDRS10] and Šoltészová et al. [ŠPBV10], we present a concept to improve the visual results of a GPU-based direct multi-volume renderer. Both approaches from literature are not directly applicable to the multi-volume case. The Ropinski approach uses, like several related attempts, a pre-calculation of light transport parameters for every voxel, which is not feasible for scenes containing many large volumes because of the tremendous memory requirements. The Šoltészová system is more memory-friendly, but requires a permanent ambient occlusion approximation kernel update, when the light source is altered. These kernel updates would interfere with the required stream coherency of our rendering system [KGB*09] and would therefore lead to a low frame-rate, when the light source is manipulated.

Method We use a simplified version of the absorption and emission scheme including single scattering and shadowing from Max [Max95]. As a phase function for the scattered light, we follow Max's primary suggestion and use the Henyey-Greenstein function $p(\theta) = \frac{1}{4\pi} \cdot \frac{1-g^2}{(1+g^2+2g\ cos\theta)^{\frac{3}{2}}}$ from [HG41], where g stands for the average cosine of the scattering angle, ranging from -1 to 1. A negative value means backward scattering, whereas a positive one means forward scattering. A value of 0 reduces the result to $\frac{1}{4\pi}$ which results in isotropic scattering, i.e., light is scattered equally in all directions.

In our algorithm, the scattering sampling points and the the scattering angle are determined from a local neighborhood of the voxel, guided by the gradient approximation at the voxel position. We assume that a strong gradient indicates a less scattering, more reflecting surface and that the gradient points in the direction of less dense, more scattering media. The scatter angle and the amount of in-scattering to the current sample position is defined by the angle between the gradient approximation at a scatter sample point and the gradient approximation at the current sample position. The cosine of the scattering angle is zero only if the direction of a scatter sample gradient is identical to the current sampling point's gradient vector. We use up to 15 scatter sample positions, depending on the strength of the gradient at the current volume sampling position. We weight their influence by the distance to the actual sampling point and the gradient magnitude at the given scatter sampling position. This scatter sampling point scheme is outlined in Figure 1. For the calculation of the light transfer through the volumes, we use the standard lighting absorption calculation which is also shown in [Max95]. All the required computations are performed on-the-fly on the GPU without the need for further parameter buffers.

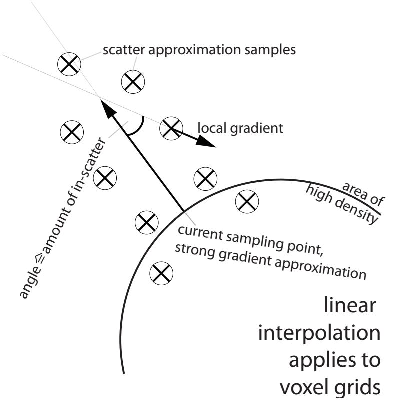

Figure 1: *Our scatter approximation sampling scheme is based on local gradients.*

Results In this section, we present some results on the performance of our new lighting calculation in comparison to a Phong-based illumination model. We tested our method on a workstation equipped with Intel QuadCore 3,16 GHz and two Nvidia Geforce 480 GPUs. As shown in Table 1, the performance impact of the new method is significant, however the frame-rates remain interactive. In Table 1, we show the results of comparison of our method and the local Phong illumination model. We use different transfer functions (TF) with varying opaque/reflective – translucent/scattering ratios. The visual difference on the test dataset is shown in Figure 2.

Conclusion We present a quick and easy to implement method to approximate scattering and shadowing for direct volume rendering of multiple intersecting datasets. Our method, while being more computationally expensive than a simple Phong-based illumination model, allows to maintain the interactive frame rates. The presented approach is able to show the details that are not visible with the local illumination model, and demonstrates an overall improvement in visual quality. **Acknowledgments:** This work was funded by the EU in FP7 VPH, contract number 223877.

	T1	T2	T3	T4
Phong Model	45	41	41	39
L1	21	19	20	18
L2	11	9	11	8

Table 1: *Performance comparison for our method in average frames per second for different transfer functions with different opaque/reflective – translucent/scattering ratios compared to a local Phong illumination model. For this test we used two registered 256^3 datasets in a 1024 x 768 viewport. (T1 = both datasets are opaque; T2 = dataset is 1 opaque, dataset 2 is translucent T3 = both datasets are half-opaque – half-scattering; T4 = both datasets are translucent; L1 = light transport; L2 = light transport including scattering.)*

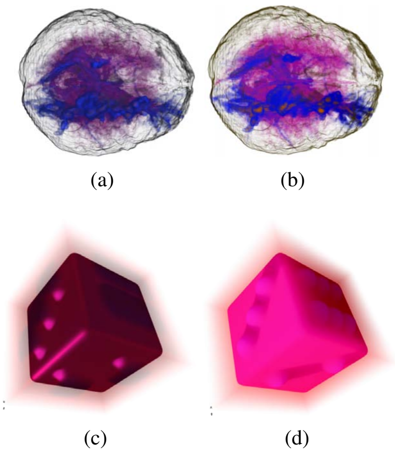

Figure 2: *One of the used test datasets: Two registered volumetric datasets (256^3 MRI and DTI-MRI of the brain), using the common Phong model (a) and our method (b) and the same transfer function. The difference is additionally illustrated with a generic dataset and an opaque transfer function peak in (c), Phong and (d) our method*

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