A SIX-FLUX TRANSFER APPROACH FOR EFFICIENT LAYERED MATERIALS RENDERING

J. RANDRIANANDRASANA$^{1,2}$, P. CALLET$^3$, L. LUCAS$^1$

$^1$UNIVERSITÉ DE REIMS CHAMPAGNE-ARDENNE, FRANCE  $^2$UNITED VISUAL RESEARCHERS, FRANCE  $^3$MINES PARISTECH, FRANCE

PROBLEM

Many objects of our everyday life include scattering volume layers (dust deposition, weathering pigments, ...). While layered materials composed of rough interfaces are well handled by state-of-the-art efficient rendering approaches, participating media layers remain poorly supported. In practice, this incurs severe energy losses yielding inconsistent dark appearances with increasing volume scattering.

REFERENCE

Belcour Guo et al. Ours

RELATED WORK

Accurate solutions: Highly accurate methods have been proposed in recent years. However, these approaches reveal impractical for low-time budget rendering due to expensive per-material precomputations [1] or because of additional variance due to their stochastic nature [2].

Efficient methods: Belcour [3] recently introduced a low computation cost multi-lobe approach. To this end, the author introduces a low-order statistical representation for light-matter interactions and derives novel equations for the framework. However, scattering volumes are poorly supported as the method does not account for back-scattering and resorts to simple scattering approximations to avoid expensive double-scattering operations. Unfortunately, the framework introduced by the author cannot be easily extended to handle both forward and backward propagating flux and scattering volumes of arbitrary depths.

REFERENCE

Belcour Guo et al. Ours

OVERVIEW

We overcome these limitations with an efficient solution based upon a transfer matrix modeling. Under this formalism, each volume and interface is described through a weighted matrix, layering operations reduce to simple matrix products, and total flux accounting for multiple scattering are obtained thanks to matrix operators.

To be fully compliant with the matrix formalism, we propose to approximate light-matter interactions within the structure with Henyey-Greenstein (HG) phase function convolution products as they reduce to simple asymmetry parameters multiplications.

REFERENCE


THE SIX-FLUX APPROACH

To achieve high fidelity appearances, we propose to isolate light having undergone one or more scattering events in a medium (secondary flux) from light not scattered by any medium in the structure (primary flux). Moreover, as a significant amount of light might be scattered back with back-scattering, we propose to split the secondary flux into forward and backward contributions.

The six-flux approach requires a transfer matrix representation. Participating media are naturally handled as they are usually described with this phase function. In this form, generic matrix operators for primary and secondary reflectances accounting for internal multiple scattering are easily derived based on the BRDF boundary conditions. We obtain the transfer matrix of a homogeneous participating medium by approximating the transport occurring in an infinitesimally thin slab and derive the matrix for any arbitrary depth with the exponential matrix method. In the case of an interface, the transfer matrix further simplifies as no interaction happens between primary and secondary flux.

To compute the shapes of the outgoing lobes with the transfer matrix formalism, we further approximate each light-matter interaction in the structure as HG phase functions convolution as they simply express as asymmetry parameters products. Thus, we describe each lobe through an (energy, mean, asymmetry) statistical representation. Participating media are naturally handled as they are usually described with this phase function. In the case of interface components, we provide a simple analytical fit for GGX-based rough interfaces.

REFERENCE

Belcour Guo et al. Ours

RESULTS

We implemented our approach in the Mitsuba renderer. All the results shown in this section use the path integrator. Our approach handles stacks of rough interfaces with visual results comparable to state-of-the-art efficient methods [3] while it suffers from drastic energy losses, our approach provides results close to the ground truth, even with strong backscattering media. Additional computational costs are mainly due to the order-six matrix products and additional lobes calculus. While stochastic approaches [2] introduce significant variance and computation cost with increasing volume scattering, the six-flux approach provides high fidelity results with a low sample budget. As the main limitation, only isotropic interfaces are currently supported due to the underlying HG representation. Future work will investigate if the approach is suitable for interactive rendering on the GPU.

REFERENCE

Belcour Guo et al. Ours

REFERENCES

