A six-flux transfer approach for efficient layered materials rendering
Joël Randrianandrasana, Patrick Callet, Laurent Lucas

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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 participating media, we propose to split the secondary flux into forward and backward contributions.

Accounting for the upward and downward directions of propagations in the structure, we thus describe the light distribution at any depth of the structure as a six-flux vector. The net balance relating the total flux sitting on each side of any stack component of the structure (interface, volume layer, or any combination of them) takes a general order-six matrix form.

In this form, generic matrix operators for primary and secondary reflectances accounting for internal multiple scatterings 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.

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 the latter suffers from drastic energy losses, our approach provides results close to the ground truth, even with strongly 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.

REFERENCES