Precomputed Multiple Scattering for Light Simulation in Participating Medium

Beibei Wang, Nicolas Holzschuch

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Beibei Wang
Nanjing Univ. of Science & Tech., Inria, Univ. Grenoble-Alpes, CNRS, LJK

Nicolas Holzschuch
Inria, Univ. Grenoble-Alpes, CNRS, LJK

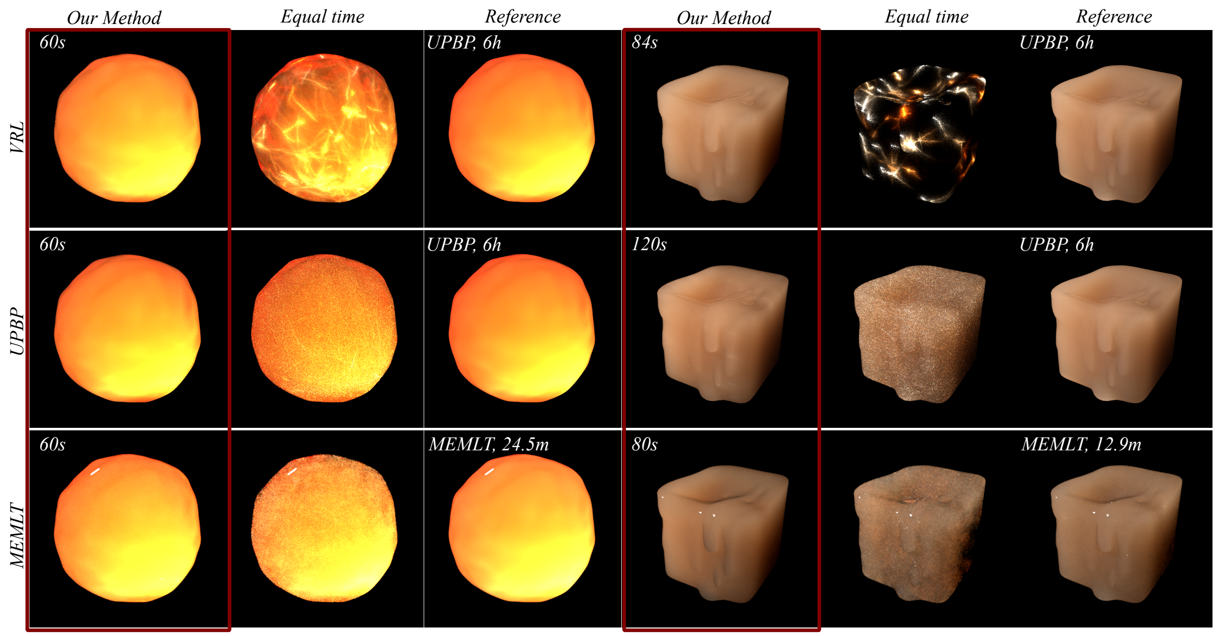

Figure 1: Our precomputed multiple scattering accelerates the convergence of existing algorithms for participating media.

CCS CONCEPTS

•Computing methodologies → Rendering;

KEYWORDS

Participating Media, Multiple Scattering, Precomputation

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1 OVERVIEW

Illumination simulation involving participating media is computationally intensive. The overall aspect of the material depends on simulating a large number of scattering events inside the material. Combined, the contributions of these scattering events are a smooth illumination. Computing them using ray-tracing or photon-mapping algorithms is expensive: convergence time is high, and pictures before convergence are low quality (see Figure 1). In this paper, we precompute the result of multiple scattering events, assuming an infinite medium, and store it in two 4D tables. These precomputed tables can be used with many rendering algorithms, such as Virtual Ray Lights (VRL), Unified Point Beams and Paths (UPBP) or Manifold Exploration Metropolis Light Transport (MEMLT), greatly reducing the convergence time. The original algorithm takes care of low order scattering (single and double scattering), while our precomputations are used for multiple scattering (more than two scattering events).

2 PREVIOUS WORKS

To address the specific issues caused by illumination simulation in participating media, Křivánek et al. [2014] extend the Photon Mapping method by combining beams, points and paths automatically in participating media, using multiple importance sampling (UPBP). Novák et al. [2012a; 2012b] used Virtual Ray Lights (VRL) or beams for light transport inside translucent materials. Jakob and Marschner [2012] extend Metropolis Light transport with a new mutation strategy based on manifold exploration, improving the sampling of specular and highly glossy paths.

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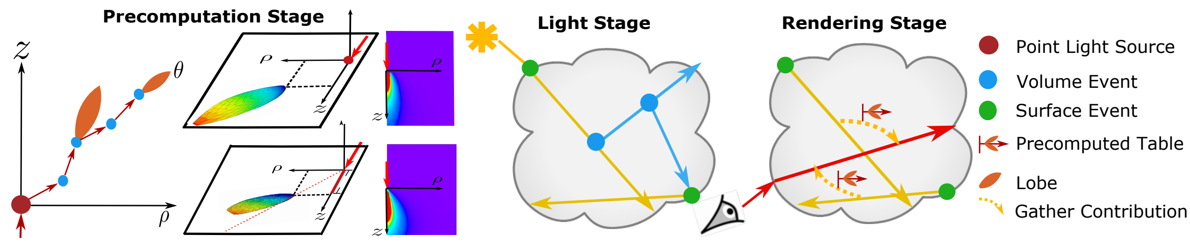

Figure 2: First, we precompute multiple scattering and store it in two tables, once per material. For rendering, we shoot and scatter rays, and then we store the rays (orange line) inside the medium after a surface event (green circle). We then use the precomputed tables to compute multiple scattering from these light rays (orange line) to the camera rays (red line).

Wang et al. [2016] presented a fast, point-based, method for global illumination with participating media, using a precomputed table for multiple scattering. Their method was limited to Bi-Directional Path Tracing, making it harder to apply it to generic scenes. We extend their work on precomputation, adding multiple scattering from a segment instead of a point, and show this precomputation can be combined with many existing illumination simulation algorithms. Moon et al. [2007] also precomputed multiple scattering, but stored the result on a set of concentric spheres.

3 PRECOMPUTED MULTIPLE SCATTERING

In the precomputation step, we assume an infinite participating medium, with the same properties as the original medium. We run two types of precomputations: with a point directional light source and with a segment light source. In both cases, we shoot photons from the light source, let them travel in the medium, being scattered or absorbed, and accumulate their contributions in a table, exploiting the problem symmetry of revolution around the direction of propagation.

At each point, indexed by its cylindrical coordinates (ρ, z) around this axis, we store the contributions as lobes in spherical coordinates (see Figure 2 and 3). We then compress these tables using a quadtree. Total computation time including compression is $\approx$ 1 mn for high-albedo materials; storage cost after compression around 100 MB.

This storage method has higher resolution, both in space and angle, than the concentric spheres method [Moon et al. 2007] (see Figure 3).

4 APPLICATION TO EXISTING ALGORITHMS

We apply our precomputation method to several global illumination algorithms: VRL, UPBP, MEMLT. Each time, we let the original algorithm handle low-order scattering, and combine it with multiple scattering computed using our precomputed tables. .

For VRL, we shoot and scatter photons in the scene, but only store the first scattering event in the medium. We use these virtual rays as the source of multiple scattering, using our tables.

For UPBP, we store the first and the second scattering events in the medium (beams or points). We use these for single and double scattering. We use the single scattering events as the source for multiple scattering.

For MEMLT, for each generated seed path inside the medium, we modify it to a *special* path, replacing path vertices far from the surface medium by a special edge, representing multiple scattering, whose weight is computed using our tables. For mutation purposes, both end points of the special edge are considered as non-specular, and the end point from the light source can not be considered as the mutation source.

We have implemented our algorithm inside the Mitsuba Renderer [Jakob 2010] for VRL and MEMLT, and inside smallUPBP [Křivánek 2014] for UPBP.

Our algorithm increases convergence speed, at the expense of introducing bias. To reduce this bias, the user can decide to let the original algorithms handle more low-order scattering events (three or four scattering events, instead of two) and use our precomputed tables for larger order multiple scattering events.

5 CONCLUSION AND FUTURE WORK

We have presented a method for precomputing multiple scattering events in participating media. These precomputed multiple scattering can be combined with many existing rendering algorithms, reducing computational costs with no visible difference. Our method works with any kind of materials, including refractive materials, high-albedo and low-albedo materials. In future work, we want to study extension to heterogeneous materials.

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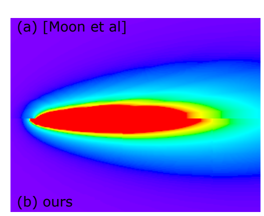

Figure 3: Multiple scattering computed using Moon et al. [2007] (top) and our method (bottom). Moon et al. use concentric spheres, causing angular artifacts, along with low resolution near the axis.