A 3D Lattice Boltzmann Method for Light Simulation in Participating Media

Albert Mink, Mathias Krause
Karlsruhe Institute of Technology
albert.mink@student.kit.edu

With this work we reveal a new approach to solve light propagation in participating media with Lattice Boltzmann Methods (LBM). The underlying analytical model for light transport in media is the radiative transport equation (RTE), which is also applied in weather forecasting, astrophysics, greenhouse simulations and more [1]. We firstly approximate RTE by the P_1 method, also known as the diffusion approximation [2]. In this step, the analytical problem is transported into the macroscopic world and appears to be a diffusion equation with an additional sink term. One advantage of this method is, that the scattering- and absorption coefficients of RTE are clearly linked with macroscopic diffusion and sink coefficients. However, there are no stream and collide equations for this kind of diffusion equation in literature. An approach where RTE is directly discretized by an quasi LBM, is given for 1D and 2D problems in [3, 4, 5]. Often, those direct discretizations deploy special geometries and lack therefore on generality. Or due to the absence of analytical solutions, the resulting LBM are evaluated by numerical solutions from Finite Volume Methods or Discrete Ordinate Methods.

The principal part of our work consists of proposing novel kinetic stream and collide equations, accordingly to the diffusion equation with additional sink term. Those equations are proposed heuristically and are valid for $D3Q7$ lattice arrangements. In order to confirm accuracy and correctness, we accomplished numerical analysis. Based on analytical solutions for a point light source in an infinite medium, numerical convergence and grid independence of the proposed 3D LBM is shown.

References

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