Advanced Topics in Computer Graphics I

Universität Bonn
Institut für Informatik II
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Sheet R11 - Delta Tracking

Hand in your solutions via eCampus by Tue, 08.07.2025, **12:00 p.m.**. Compile your solution to the theoretical part into a single printable PDF file. For the practical part, hand in a single ZIP file containing only the exercise* folder within the src/ directory. Please refrain from sending the entire framework.

Assignment 1) Delta Tracking *(6 Pts)*

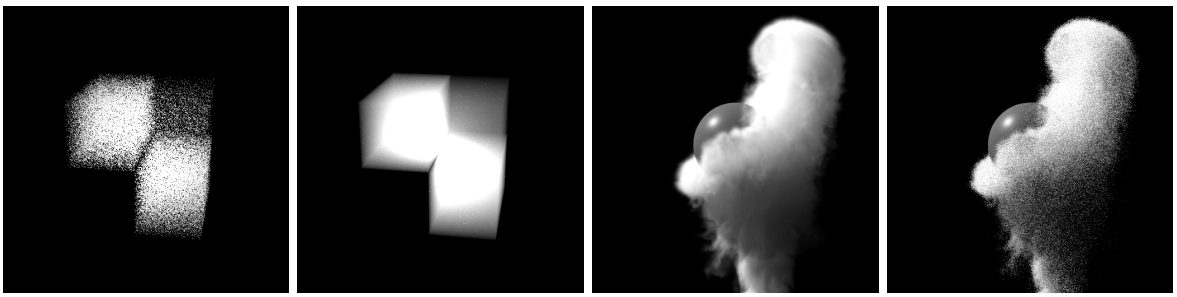

Figure 1: On the left, a unit cube is filled with heterogeneous participating medium. In the lower left corner, the medium has zero density, and in the thin upper right corner, it has half the density of the thicker regions. On the right, a point light source illuminates a heterogeneous smoke plume wrapping around a solid sphere. The inner images have been rendered with 10k samples per pixel, and the outer images with 10 samples per pixel. To obtain these renderings, run `./bin/exercise11_DeltaTracking -s data/exercise11_DeltaTracking/cube_cutout.xml` and `./bin/exercise11_DeltaTracking -s data/exercise11_DeltaTracking/smoke_plume.xml`, respectively.

Since there is only one week left in the semester, we decided not to do a final project extending multiple weeks, and instead issue a final practical exercise sheet.

In this exercise, the pathtracing framework is extended by heterogeneous participating media. The density of the medium that fills the space between the surfaces in the scene is allowed to vary across space. For simplicity, we assume that all color channels are scattered equally and that there is no absorption, only scattering in the medium. Your task is to complete the `HeterogeneousMedium` class in the `heterogeneousmedium.*` source files.

a) Implement the delta-tracking algorithm[1] for sampling a medium event from a heterogeneous medium with varying scattering coefficient by completing the `sample_scattering_event_delta_tracking()` function in `heterogeneousmedium.cu`. If no medium event was found before the given maximum distance, set the distance to -1 to indicate that no medium event was sampled along the distance and we are in the "transmission" event. Note: Since the delta-tracking algorithm samples the target distribution exactly, you can simply set the `result.transmittance` and `sampling_pdf` to 1.

b) Implement the method for estimating the transmittance between two points in the heterogeneous medium in the `estimate_transmittance()` function. You can either use the algorithm based

on delta tracking, which yields higher variance, or the ratio-tracking algorithm, both presented by Novák et al. [1]

Assignment 2) Tracking *(4 Pts)*

Consider a ray traversing inside a volume from point a to b along the ray $x = x_0 + t\omega$.

a) Describe the step-by-step process of sampling the free-flight distance of a particle using delta-tracking. Write down the formulas for the individual steps.

b) In what scenarios would delta-tracking be particular advantageous over traditional ray marching?

c) Discuss the difference between delta-tracking and ratio-tracking. What are the advantages/disadvantages of both methods?

References

[1] Jan Novák, Andrew Selle, and Wojciech Jarosz. Residual ratio tracking for estimating attenuation in participating media. *ACM Trans. Graph.*, 33(6):179–1, 2014. URL: `https://cs.dartmouth.edu/wjarosz/publications/novak14residual.pdf`.

Good luck!