Week 9

Until this point in the course, you have only been working with surfaces. Nothing in the volumes between the surfaces has affected the rays you have been tracing. For most real materials, there is a lot going on underneath the surface. The following exercises are about volume rendering.

Learning Objectives

- Evaluate the radiative transfer equation using Monte Carlo integration.
- Simulate absorption in homogeneous transparent materials.
- Simulate scattering and absorption in homogeneous turbid materials.
- Use the Henyey-Greenstein phase function for simulating axially symmetric scattering anisotropy.

Volume Rendering

Before working on the exercises make sure that you understand the radiative transfer equation (RTE) including the nature of the *direct transmission* term and the *diffusion* term in this equation.

- Load a glass of wine (`glass_wine.obj`) into your ray tracer. Use a bright background color.
- Most wine is almost exclusively absorbing. Implement a shader that computes direct transmission for rays passing through a volume. Render the wine using this shader and store the resulting image. (In the `pathtrace` project of the course framework, implement the `shade` and `get_transmittance` functions in `Volume.cpp`.)
- Switch the material of the liquid in the wine glass to low fat chocolate milk. Chocolate milk is highly scattering because of the protein, fat, and chocolate particles it contains. The scattering properties of low fat chocolate milk have been measured by Narasimhan et al. [2006, see reference below]. (The low fat chocolate milk material has already been added to `glass_wine.mtl` and `media.mpml`.)
- Implement multiple scattering in a homogeneous volume. Do this by implementing a shader that evaluates the diffusion term using Monte Carlo integration (path tracing).[1] Make sure that your shader also includes the direct transmission term. (In the framework, implement the `sample_HG` function in `sampler.h`, the `trace_HG` function in `PathTracer.cpp`, and the `shade` function in `MCVolume.cpp`. HG is short for the Henyey-Greenstein phase function.)
- Render the wine glass containing chocolate milk both using direct transmission only and the full solution. In addition, try to put the wine back in the glass and render it using the full solution. Write down the statistics of the path tracings and store the resulting images.

Week 9 Deliverables

Path traced images showing a glass of wine and a glass of chocolate milk. Discuss the difference between direct transmission only and the full solution. Include relevant code and render log (number of triangles, number of samples, render time, number of splits, etc.). Answer the following question.

How would it be possible for a renderer to support volumes embedded within one another?

[1] Please note that you have to use looping instead of recursion to avoid the stack space limit. And the Monte Carlo integration is much easier if rays that enter a scattering volume are dispersed into individual colour bands.

Reading Material

The curriculum for Week 9 is

P Sections 11.1–11.3, 14.7. *Volume Scattering*.

- Frisvad, J. R., Christensen, N. J., and Jensen, H. W. Predicting the appearance of materials using Lorenz-Mie theory. In W. Hergert and T. Wriedt, eds., *The Mie Theory: Basics and Applications*, Springer Series in Optical Sciences, Vol. 169, Chapter 4, pp. 101-111, July 2012.

Alternative literature available online or uploaded to CampusNet:

- Cerezo, E., Pérez, F., Pueyo, X., Seron, F. J., and Sillion, F. X. A survey on participating media rendering techniques. *The Visual Computer 21*(5), pp. 303-328, June 2005.
- Binzoni, T., Leung, T. S., Gandjbakhche, A. H., Rüfenacht, D., and Delpy, D. T. The use of the Henyey-Greenstein phase function in Monte Carlo simulations in biomedical optics. *Physics in Medicine and Biology 51*, pp. N313–N322, 2006.

Additional resources:

P Chapter 16–16.4. *Volume Rendering*.

- S. G. Narasimhan, M. Gupta, C. Donner, R. Ramamoorthi, S. K. Nayar, and H. W. Jensen. Acquiring scattering properties of participating media by dilution. *ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH 2006)*, Vol. 25, No. 3, pp. 1003–1012, July 2006.