Worksheet 7

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. The wine material is "Wine (merlot)" from Narasimhan et al. [2006, see reference below]. Use an environment map for the background.
- 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. (CPU framework: implement `shade` and `get_transmittance` in `Volume.cpp`. GPU framework: implement `__closesthit__absorbing` in `shaders.cu`.)
- Extend your shader for glossy materials from the previous worksheet, so that it can also take absorption into account. Based on the extinction coefficient of the medium that a ray passed through, use a Russian roulette to check for absorption or transmission as in the volume shader just implemented. Render a glossy metal bunny. (Extend the `MCGlossy` shader in the CPU framework or `__closesthit__glossy` in the GPU framework to account for absorption.)
- 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 integral form of the radiative transfer equation using Monte Carlo integration (path tracing).[1] Render the wine glass with chocolate milk. (Implement the `sample_HG` function in `sampler.h`. HG is short for the Henyey-Greenstein phase function. CPU framework: implement `trace_HG` in `PathTracer.cpp`, and `shade` in `MCVolume.cpp`. GPU framework: implement `__closesthit__volume` in `shaders.cu`.)

Worksheet 7 Deliverables

Path traced images showing a glass of wine, a glossy metal bunny, and a glass of chocolate milk. Include relevant code and number of samples. Answer the following question.

How is it 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 Worksheet 7 is

P Sections 11.1–11.3. *Volume Scattering*.

P Sections 15.1–15.3. *Volume Rendering*.

Alternative literature available online or uploaded to DTU Inside File Sharing:

- 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. https://doi.org/10.1007/s00371-005-0287-1
- Hanrahan, P., and Krueger, W. Reflection from layered surfaces due to subsurface scattering. *Computer Graphics (SIGGRAPH 93)*, pp. 165–174. 1993. https://doi.org/10.1145/166117.166139

Additional resources:

- Narasimhan, S. G., Gupta, M., Donner, C., Ramamoorthi, R., Nayar, S. K., and Jensen, H. W. Acquiring scattering properties of participating media by dilution. *ACM Transactions on Graphics (SIGGRAPH 2006)*, Vol. 25, No. 3, pp. 1003–1012. July 2006. https://doi.org/10.1145/1179352.1141986
- Novák, J., Georgiev, I., Hanika, J., and Jarosz, W. Monte Carlo methods for volumetric light transport simulation. *Computer Graphics Forum (EG 2018) 37*(2):551–576. May 2018. https://doi.org/10.1111/cgf.13383