02941 Physically Based Rendering DTU Compute

Worksheet 6

So far you have been working with perfectly diffuse (Lambertian) and perfectly specular materials. Naturally, there are several models to describe *glossy* materials, that is, materials which are in-between perfectly diffuse and perfectly specular. These models are typically based on a microfacet distribution (see **P**: Sec. 8.4) or based on measurements. The following exercises are about implementing shaders for glossy materials.

Learning Objectives

- Render glossy metal and glass surfaces
- Use a microfacet BSDF model for simulating light scattering at an interface (material surface).
- Use importance sampling for improved convergence when rendering with glossy surfaces.
- Analyse the physical plausibility of a BSDF.

Ray Tracing

The Torrance-Sparrow microfacet model for computing the scattering of light at an interface has gained significant attention in recent years. We will therefore implement this model in the following exercises and use it for rendering glossy glass and metal surfaces.

- Return to the scene with a bunny in an outdoor environment (see Worksheet 2). Change the material used for the bunny, so that it uses a glossy material with a well-defined index of refraction and shininess parameter (In the frameworks, a glossy shader is used when the material is set to use `illum 2`. The index of refraction is set using the `Ni` option in the MTL material assigned to the bunny or using the additional data available in `media.mpml` as when rendering metals. The shininess is set using the `Ns` option in the MTL material.)
- Pick a normal distribution for your shader (Blinn, Beckmann, GGX) and implement a function that samples a normal according to the chosen distribution. A description of different normal distributions is available in the paper by Walter et al. [2007, see reference below]. (In the frameworks, implement a function for sampling a microfacet normal in `sampler.h`.)
- Implement a shader for glossy materials based on the importance sampling of the Torrance-Sparrow model described by Walter et al. [2007]. You can use the shininess parameter for the Blinn distribution or the reciprocal of the shininess as the roughness or distribution width parameter for other models. (Some helper functions are provided in the file `microfacet.h`. CPU framework: implement `shade` in `MCGlossy.cpp`. GPU framework: implement `__closesthit__glossy` in `shaders.cu`, but postpone the DIRECT section.)
- Explore the parameter space (modify the shininess `Ns` and the index of refraction `Ni` in the MTL file, glass often has an `Ni` of 1.5 and silver has an `Ni` of 0.2). Consider whether your shader could fully support shading of rough metallic surfaces by retrieving RGB Fresnel reflectance. Try this or explain how it could be done. Store images illustrating the different effects that your BSDF model can capture.
- (**Optional.**) Implement a shader that evaluates the microfacet BSDF model for direct sampling of light sources and include this illumination in your shader based on importance sampling.
  (CPU framework: implement `shade` in `Glossy.cpp`. As indicated by the code in `MCGlossy.cpp`, the result from the direct sampling shader can be added to the result obtained by importance sampling indirect illumination. GPU framework: implement the DIRECT section of `__closesthit__glossy`.)

Worksheet 6 Deliverables

Images of the bunny in an environment with different types of materials spanning from transparent to matte to shiny metal. A discussion of the different types of materials that the microfacet model can represent. Optionally, also images including illumination due to a directional sunlight.

Reading Material

The curriculum for Worksheet 6 is

P Sections 8.4–8.5. *Microfacet Models*.

P Sections 13.10, 14–14.1.3. *Importance Sampling* and *Sampling Reflection Functions*.

Alternative literature available online or uploaded to CampusNet:

- Walter, B., Marschner, S. R., Li, H., and Torrance, K. E. Microfacet models for refraction through rough surfaces. In *Proceedings of Eurographics Symposium on Rendering (EGSR 2007)*, pp. 195–206, 2007. https://doi.org/10.2312/EGWR/EGSR07/195-206

Additional resources:

- Torrance, K. E., and Sparrow, E. M. Theory for off-specular reflection from roughened surfaces. *Journal of the Optical Society of America 57*(9):1105–1112, September 1967. https://doi.org/10.1364/JOSA.57.001105

- Meneveaux, D., Bringier, B., Tauzia, E., Ribardière, M., and Simonot, L. Rendering rough opaque materials with interfaced Lambertian microfacets. *IEEE Transactions on Visualization and Computer Graphics 24*(3):1368–1380, March 2018. https://doi.org/10.1109/TVCG.2017.2660490