02941 Physically Based Rendering — DTU Compute

Worksheet 5

Caustics and diffuse interreflections have been missing from your renderings in the previous exercises. We will now include these effects. The focus of this worksheet is path tracing. Most of what you have been doing for the ray tracing part of the previous exercises has been leading up to path tracing. So, if you finished those exercises, the following might be little more than a walk in the park.

Learning Objectives

- Implement path tracing.
- Do unbiased rendering of diffuse interreflections and caustics.
- Use splitting and Russian roulette in global illumination.
- Explain the visual effect of indirect light paths.

Path Tracing

The Cornell box was originally constructed to exhibit diffuse interreflections. It is therefore not surprisingly a good test scene when one would like to capture this type of effect. In the following, you will render the two classic Cornell box scenes: the box with two blocks and the box with a reflective sphere and a transmissive sphere. Reflective and transmissive materials (metal and glass, for example) are rendered in the same way in path tracing as you rendered them in the exercises for Worksheet 3. Diffuse reflection is related to the ambient occlusion you implemented in the exercises for Worksheet 4. Although, usually, you will only sample one new ray at each intersection in path tracing.

- Load the Cornell box (`CornellBox.obj`) and the blocks inside it (`CornellBlocks.obj`) into your renderer. Set the background illumination to 0 and the number of area light samples to 1 (you can do this in `RenderEngine.cpp`). Render an image without too much noise that includes diffuse interreflections (colour bleeding). Note the rendering time and the number of samples you used. (Press 't' in the CPU framework or 'r' in the GPU framework to toggle progressive path tracing on/off.)
  Implementation: To capture caustics and diffuse interreflections, we implement Monte Carlo path tracing for Lambertian surfaces. Use your shader for Lambertian surfaces to integrate direct lighting explicitly. When you do this, the radiance contributed from the light source is computed explicitly at each surface point. This means that you should not add the emission from the light source when secondary rays hit the source. Make sure this point is handled correctly in you renderer. Use Russian roulette (with the diffuse reflectance) to determine whether a secondary ray should be traced. Trace a secondary ray in a direction sampled on the hemisphere over the surface point. (CPU framework: implement the `shade` function in `MCLambertian.cpp`. Note that the Monte Carlo Lambertian shader is used when you press '3' on the keyboard. GPU framework: implement the INDIRECT section of `__closesthit__arealight`.)
- Replace the blocks in the Cornell box by a silver sphere (`CornellLeftSphere.obj`) and a glass sphere (`CornellRightSphere.obj`). Render an image without too much noise. Note the rendering time, and the number of samples per pixel.
- The primary caustics are obvious in this image (light paths $L(S_r|S_tS_t)DE$). The bright dots (or soft illumination, if the path tracing goes on long enough) distributed almost evenly around the scene are due to reflection, the bright spherical area below the glass sphere is due to direct transmission. However, there are also several secondary caustics in the image (these involve an extra diffuse or specular interaction before taking the path of a primary caustic). Point out where the secondary caustics appear and explain their origin in terms of the path that light took.
- Test splitting versus Russian roulette up to different trace depths in the shaders for transparent objects and metals. Investigate how this influences the number of samples needed to render the caustics.

Worksheet 5 Deliverables

Cornell box images (with the Cornell blocks, with a silver ball and a glass ball). Include relevant code and please give details about the number of samples per pixel and details of where and how splitting was used instead of Russian roulette. Include a description of the secondary caustics in the Cornell box with two balls.

Reading Material

The curriculum for Worksheet 5 is

P Sections 14.4–14.5. *The Light Transport Equation* and *Path Tracing*.

Alternative literature available online or uploaded to CampusNet:

- Philip Dutré. *Global Illumination Compendium*. Lecture Notes, Katholieke Universiteit Leuven, September 2003. https://people.cs.kuleuven.be/~philip.dutre/GI/.
- Philip Dutré. The Rendering Equation and Path Tracing. In *State of the Art in Monte Carlo Global Illumination*, ACM SIGGRAPH 2004 Course Notes, Course 4, 2004. https://doi.org/10.1145/1103900.1103905

Additional resources:

- The Cornell box (data and history): https://www.graphics.cornell.edu/online/box/