Week 5

Caustics and diffuse interreflections have been missing from your renderings in the previous exercises. We will now include these effects. The exercises for this week focus on 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 surprising that it is 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 Week 3. Diffuse reflection is related to the ambient occlusion you implemented in the exercises for Week 4. Although, usually, you will only sample one new ray at each intersection in path tracing.

- To capture caustics and diffuse interreflections, 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 tracer. Use Russian roulette (with the diffuse reflectance) to determine whether a secondary ray should be traced. Trace secondary rays in directions sampled on the hemisphere over the surface points. (In the `pathtrace` project of the framework, implement the `shade` function in `MCLambertian.cpp`. Note that the Monte Carlo Lambertian shader is used when you press '3' on the keyboard.)
- Load the Cornell box (`CornellBox.obj`) and the blocks inside it (`CornellBlocks.obj`) into your ray tracer. Set the background illumination to 0 (in line 86 of `RenderEngine.cpp`). Render an image without too much noise using your implementation of Monte Carlo path tracing for Lambertian surfaces. Note the rendering time and the number of samples you used. Save the resulting image. (In the framework, press 't' to continually improve an image using path tracing.)
- To improve rendering efficiency, use splitting instead of Russian roulette when you hit the first diffuse surface. (In the framework, implement the `split_shade` function in `MCLambertian.cpp`.)
- Render another image which uses splitting at the first diffuse surface. Let it run for approximately the same time as the previous rendering which did not use splitting. Note the number of samples you take when you split, the rendering time, and the number of samples per pixel. (The framework is set up to trace 5 samples when splitting. See line 120 of `pathtrace.cpp`.) Save the resulting image.
- 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 number

of samples you take when you split, the rendering time, and the number of samples per pixel. Save the resulting image.

- 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.

Week 5 Deliverables

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

Reading Material

The curriculum for Week 5 is

P Sections 15.2–15.3.4. *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. http://www.cs.kuleuven.ac.be/~phil/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.

Additional resources:

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