Week 10

You may feel that the volume rendering results from last week are slightly disappointing. Volumes (and real objects for that matter) take a lot of their appearance from the illumination incident from the surroundings. A flatly coloured background will rarely produce realistic results. Using an environment map heightens the realism considerably. We will do this in the following. Then, given optical properties as input, you should be able to render a homogeneous participating medium or translucent material in realistic surroundings. The next step is to acquire optical properties that accurately capture the appearance of real-world materials. The assignment in this area will be open-ended. Creativity is encouraged.

Learning Objectives

- Explain high dynamic range (HDR) imaging and use RGBE encoded images.
- Use an HDR environment map as an infinitely distant area light source.
- Combine shading and tracing techniques with theory for light-material interaction.
- Analyse real-world light-material interaction and propose ways of simulating it.

High Dynamic Range Imaging

To use high dynamic range environment maps, a loader for a high dynamic range image format is needed. And once the map is loaded, it must be used in the right way. The following exercises are about handling high dynamic range environment maps.

- Go to Paul Debevec's web page (see references below) and choose a light probe that you would like to use as your environment map. Download it in .hdr format and load it into your ray tracer. (In the `pathtrace` project of the framework, set the `bgtex_filename` variable in the `Initialization` section of `RenderEngine.cpp`.)
- The .hdr format stores high dynamic range data using RGBE encoding. Implement conversion of RGBE to floating point data. (In the framework, implement the `convert` function in `HDRTexture.cpp`. Please note that 128 is subtracted from the exponent `e` before `convert` is called.)
- A light probe is a transformed photo (or two photos) of a mirror sphere. To use it as an environment map, you have to project a direction to a set of uv-coordinates that can be used to make a look-up in the texture. For the light probes at Paul Debevec's web page, this is done using the angular map. Implement the angular map. (In the framework, implement the `project_direction` function in `SphereTexture.cpp`.)
- Ensure that your path tracer makes a look-up into the environment map when no geometry is encountered. Redo your renderings of a glass of wine and a glass of chocolate milk from last week. This time with background illumination loaded from an HDR environment map. It is acceptable to render the images in low resolution as they will take many samples (thousands) before they converge.

Appearance Modelling

During the course, we have identified some of the key optical properties needed for physically based modelling of different types of materials and visible phenomena. The following is a short summary of these optical properties and the uses that we have discussed.

- The complex refractive index is useful for rendering smooth metal surfaces, transparent and coloured glasses and liquids as well as dispersion of light.
- The BRDF is useful for rendering opaque materials that exhibit diffuse, rough, or glossy reflection of light. This could be materials such as metallic paints, brushed steel, and wood.
- Scattering properties are useful for rendering volumes and translucent materials such as milk, skin, porcelain, and plants. They capture the scattering of light by particles under the surface of an object.

The assignment is now as follows.

- Go outside the lab and find a material or visible phenomenon that you would like to model. Take (or find) a photograph of whatever you choose.
- Write down what type of rendering method and optical properties you would need to render the appearance of the chosen material or phenomenon.
- Search the literature to see if the needed optical properties are available, and to see if a rendering method already exists. Write down references and a short description of the literature you found.
- Describe how you would do the rendering using the methods covered in this course. Include in the description any difficulties and extensions of the framework that might be necessary.

Week 10 Deliverables

Path traced images showing a glass of wine and a glass of chocolate milk in an HDR environment. Include relevant code and render log (number of triangles, number of samples, render time, number of splits, etc.). A description of how you would render the appearance of a material or a visible phenomenon that exists in the real world. Please include a photograph of the chosen material or phenomenon as well as any optical properties that you might find in the literature, and give references.

Reading Material

The curriculum for Week 10 is

- **P** Sections 12.5 and 14.6.5. *Infinite Area Lights*.
- Reinhard, E., Ward, G., Pattanaik, S., Debevec, P., Heidrich, W., and Myszkowski, K. *High Dynamic Range Imaging: Acquisition, Display and Image-Based Lighting*, second edition, Morgan Kaufmann/Elsevier, 2010. Excerpt: Sections 3-3.3.1 and 11.3-11.4.
- 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, Sections 4.3–4.5, July 2012.

Alternative literature available online or uploaded to CampusNet:

- Ward, G. High dynamic range image encodings. In *ACM SIGGRAPH 2004 Course Notes*, 2004.
- Debevec, P. Image-based lighting. *IEEE Computer Graphics and Applications 22*(2), pp. 26–34, 2002.
- Frisvad, J. R., Christensen, N. J., and Jensen, H. W. Computing the scattering properties of participating media using Lorenz-Mie theory. *ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH 2007) 26*(3), Article 60, 2007. http://orbit.dtu.dk/getResource?recordId=208632&objectId=1&versionId=2

Additional resources:

- Paul Debevec has made many useful contributions to high dynamic range imaging. Check out his web page: http://www.debevec.org/
- Captured light probes are available at http://www.debevec.org/Probes/

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