Curvature-Dependent Reflectance Function for Rendering Translucent Materials

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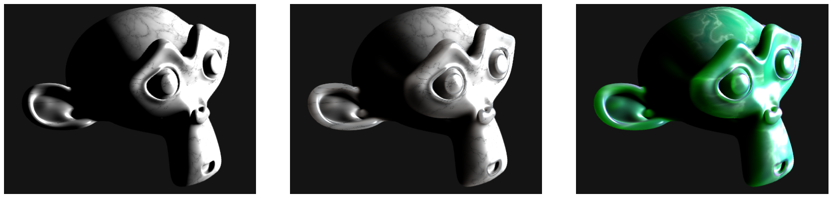

(a) Lambert (Marble) (b) Our method (Marble) (c) Our method (Jade)

Figure 1: *Synthesized images of marble objects (a), (b) and Jade (c).*

1 Introduction

Simulating sub-surface scattering is one of the most effective ways for realistically synthesizing translucent materials such as marble, milk and human skin. In previous work, the method developed by Jensen et al. [2002] significantly improved the speed of the simulation. However, the process is still not fast enough to produce real-time rendering. Thus, we have developed a curvature-dependent reflectance function (CDRF) which mimics the presence of a sub-surface scattering effect.

The process we have developed is faster, simpler and easier to control than that developed by Kolchin[2007]. In our approach, we make use of only one parameter σ_0 that represents the intensity of light scattering inside the material. σ_0 can be obtained not only by curve-fitting simulated sets of data, but can also be manually determined by an artist. Furthermore, this is easily implementable on the GPU and doesn't require any complicated pre-processing or multi-pass rendering, as is often the case in this area of research [Mertens et al. 2003; d'Eon et al. 2007].

2 Curvature-Dependent Reflectance Functions

The effects of subsurface scattering tend to be more noticeable on smaller, more intricate objects than on simpler, flatter ones. This seems to indicate that surface complexity largely determines these effects. For the purposes of our research, we decided to use curvature to represent surface complexity, combined with a simple local illumination model.

Prior to rendering, it is necessary for subsurface scattering profiles to be acquired and interpreted for our algorithm. We rendered several spheres of varying radii to reveal the relationship between curvature κ and radiance L_d. The effects of subsurface scattering are simulated on each of the spheres using photon mapping. The spheres are illuminated by a directional light from the left side of the sphere, as shown in Figure-2-(a). The calculated color of each pixel on the equatorial line represents a relation of θ (the angle between the light direction and the normal vector) and the radiance of the sphere's particular curvature (Figure-2-(b)). We then fit a curve to the obtained data using CDRF f_r below.

$$f_r(\theta, \kappa) = (L_i * g)(\theta) \tag{1}$$

CDRF is defined by the convolution of incident light energy L_i and a gauss function $g(\theta, \sigma)$ to provide a bluring effect. L_i and $g(\theta, \sigma)$ are given by

$$L_i(\theta) = \max(\cos(\theta), 0) \tag{2}$$

$$g(\theta, \sigma) = \frac{1}{\sqrt{2\pi\sigma(\kappa)^2}} \exp\left\{-\frac{\theta^2}{2\sigma(\kappa)^2}\right\} \tag{3}$$

$\sigma(\kappa)$ represents the intensity of scattering inside the material, and is assumed to be in inverse propotion to radius r. Therefore, $\sigma(\kappa) \approx \frac{\sigma_0}{r} = \sigma_0\kappa$. To minimize RMS error between the obtained data-set and f_r, we acquire the optimal parameter σ_0 (see Figure-2-(c)).

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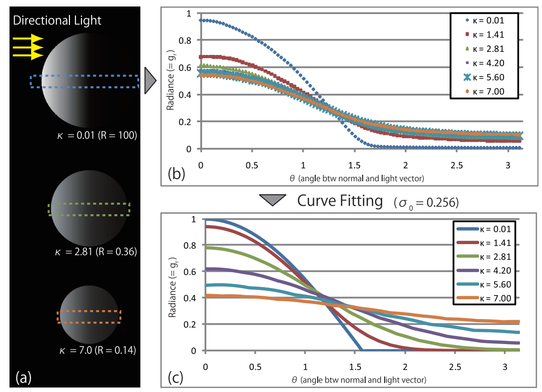

Figure 2: *Acquiring a CDRF and the parameter σ_0*

3 Results

Figures1-(a) and (b) are synthesized images of a marble object, and Figure1-(c) is an example of a jade object. To render Figure1-(b) we acquired the scattering parameter σ_0 for Figure1-(b) using curve-fitting. The results shown in Figure1-(c) were obtained by setting the parameters by hand. We implemented our algorithm as a hardware-accelerated real-time renderer with a HLSL pixel shader.

4 Conclusion

We have developed a method for approximating the effects of subsurface scattering using a curvature-dependent reflectance function. Since the function is a local illumination model, we are able to synthesize realistic translucent materials in real-time. Furthermore, our system can be easily used to stylize subsurface scattering effects because only one parameter σ_0 is required. In our future work, we will apply our techniques to deformable objects by computing curvature on the GPU.

References

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