Circle Tracing for Subsurface Scattering

Benjamin Legros*
Mercenaries Engineering

Cyril Corvazier
Mercenaries Engineering

(a) The Little Prince

(b) Lee Perry-Smith

Figure 1: *Examples of Subsurface scattering on (a) The Little Prince movie and (b) Lee Perry-Smith Infinite Realities scan.*
The Little Prince ©2015 LPPTV - LITTLE PRINCESS - ON ENTERTAINMENT - ORANGE STUDIO - M6 FILMS - LUCKY RED

Abstract

Rendering of translucent materials such as skin, marble or wax is a requirement for animation and visual effects production, either photo realistic or non photo realistic styles. Monte-Carlo integration of light transport by simulating scattering events of light within the translucent medium is prohibitive and difficult to parametrize for artistically driven applications.

Light transport in a medium is modeled as a BSSRDF that characterizes the propagation of light from an entry point x_i to an exit point x.

$$L_o = \int_M \int_\Omega f(x, n, \omega_o, x_i, n_i, \omega_i) L_i cos\theta_i d\omega_i dx_i$$

We assume $f = f_s(\|x - x_i\|) * f_t(n, \omega_o, n_i, \omega_i)$ as the product of a scattering profile function and a transmission function.

[King et al. 2013] proposed a disk based sampling technique to importance sample the f_s term. We propose in this presentation a different strategy that samples points on the surface at an exact distance, even on non flat surfaces, and doesn't require additional strategies that would potentially result in no sample at all.

Keywords: subsurface scattering, ray tracing, importance sampling

Concepts: •**Computing methodologies** → **Ray tracing;** *Reflectance modeling;*

*e-mail:legros@mercs-eng.com

SIGGRAPH '16, July 24-28, 2016, Anaheim, CA,
ISBN: 978-1-4503-4282-7/16/07
DOI: http://dx.doi.org/10.1145/2897839.2927451

Circle based sampling

Our technique samples x_i on the surface by tracing a circle of radius r, centered on x, perpendicular to the surface, and rotated around n of a random angle ϕ. All intersections are recorded, and the incoming radiance is estimated at one of these points, chosen at random.

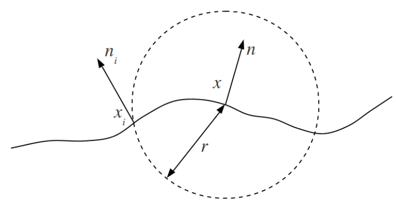

Figure 2: *Circle tracing M*

The circle radius is sampled by importance, using the scattering profile. For Gaussian scattering profile, r and ϕ can be sampled using the Box-Muller transform. Local illumination at xi is weighted by $1/\sqrt{1 - n_i.d^2}$, with respect to the surface inclination to the circle tangent.

Circle tracing

We implemented a circle tracer, similar to a ray tracer, to determine the intersection of a triangular mesh with a circle, based on our existing BVH acceleration structure. The BVH traversal is adapted to replace ray/bounding volume test with circle/bounding volume test, and ray/triangle test with circle/triangle test.

Half circles

For flat surfaces, a circle intersects twice the surface. This leads to using three random variables in simple cases. Using only half circle instead, flat surfaces intersect only once, which results in less variance (as only two random variables are used instead of three.)

This also reduces the number of hit tests to perform.

BSSRDF refinement

Since BSSRDFs assume an infinitely flat surface, they can't properly model complex structures such as lips, eye corners, or eye lids, where surface folding is important. This results in noticeable light leaking, especially in the situation of two points facing each other.

We implemented $f_t = mix(1, n.ni^+, n.d^+)$ where $d = \frac{xi-x}{\|xi-x\|}$ as a simple filter for surface points facing each other. f_t is also as a weighting function to choose the sampling point x_i in case there are several possible intersections.

(a) (b)

Figure 3: *Surface folding (a) without filtering of front facing scattering points, (b) with filtering. Light scattering from the lower lip to the upper lip is properly filtered out.*

Surface features, such as n_i and diffuse color are evaluated to benefit from bump/normal maps and simulate diffuse color blurring as suggested by [d'Eon and Luebke 2007].

Discussion

This technique was implemented in Guerilla Render to replace the previous point cloud based implementation, and extensively used on The Little Prince. This allows faster previewing, as it doesn't require precomputing irradiance, and allows progressive rendering, as it doesn't evaluate the full irradiance but simply relies on the Monte-Carlo integrator. It perfectly samples flat surfaces, and doesn't require extra sampling strategies for non flat surfaces.

We note that this technique doesn't handle large scattering radius very well (compared to the surface curvature) as there may be no intersection at all (fingers tips) but the BSSRDF framework generally performs poorly in these cases, as it suffers from energy loss. Full volumetric integration is preferable then.

Also, non isotropic scaling of a mesh makes the hit tests rather complex and less efficient to implement.

References

D'EON, E., AND LUEBKE, D., 2007. Advanced techniques for realistic real-time skin rendering. GPU Gems 3 Addison Wesley.

JENSEN, H. W., MARSCHNER, S. R., LEVOY, M., AND HANRAHAN, P., 2001. A practical model for subsurface light transport. ACM SIGGRAPH 2001.

KING, A., KULLA, C., CONTY, A., AND FAJARDO, M., 2013. Bssrdf importance sampling. ACM SIGGRAPH 2013 Talk, July.