Real-Time Rough Refraction via LEAN Mapping and Gaussian Sum Reduction

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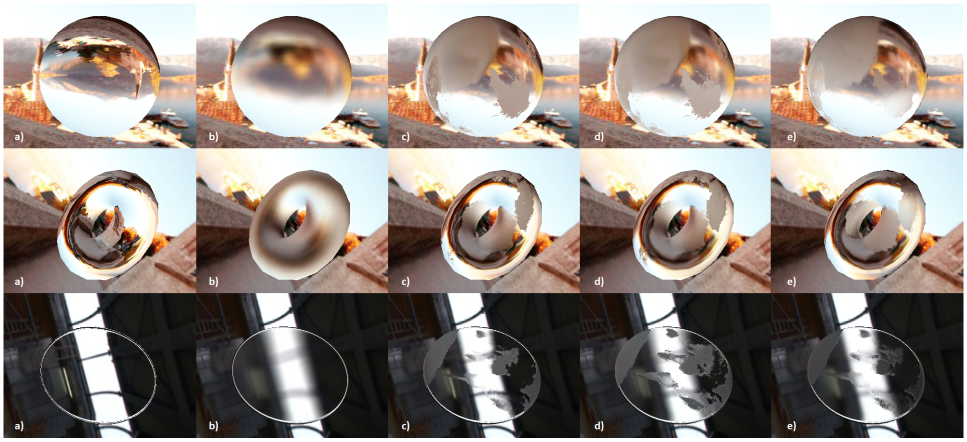

Figure 1: *Different refraction techniques . a) perfect refraction [Wyman 2005a]; b) rough refraction with* $\kappa = 835$ *[De Rousiers et al. 2011]; c) our rough refraction via LEAN mapping with roughness* $\kappa \in [0, 5000]$*; and d) our rough refraction via Gaussian sum reduction with 4 subdivisions. e) ground truth (2500 samples, no total internal refraction).*

Rough refraction commonly occurs when light scatters on rough transparent surfaces. It presents a computational challenge, as every pixel's color depends on incoming light from numerous directions. De Rousiers et al. [2011] compute rough refraction interactively using a convolution of Gaussian normal and transmittance distribution functions (NDFs and BTDFs), but their work is limited to a constant roughness surfaces. We introduce two methods that allow for varying roughness by representing surface normals using LEAN mapping and Gaussian sum reduction (GSR).

Our Methods

LEAN mapping [Olano and Baker 2010] accumulates Gaussian lobes in a mip-map, using linear interpolation of second moments to compute lobes at multiple scales. We use LEAN mapping to represent NDFs on back facing surfaces, allowing us to convolve the lobes of varying sizes that arise from differing roughness on front refractive surfaces. Then we use a Gaussian BTDF at front surfaces, with σ dependent on surface roughness. We also intersect this lobe with the back refraction surface, find the NDF based on lobe size, and convolve for the outgoing refraction lobe. Finally, we use elliptical weighted averaging [Mavridis and Papaioannou 2011] to approximate anisotropic Gaussian lobes as a sum of isotropic lobes.

We also use a GSR algorithm [Runnalls 2007] to avoid undesired averaging of lobes, which usually arises during mip-mapping. We first divide the hemisphere into several subdivisions (e.g. 4 parts), then we merge them using simplified formulas below in every subdivision. Finally, we obtain one Gaussian for each subdivision and we sum them together.

$$\mu = \omega_1\mu_1 + \omega_2\mu_2$$

$$\sigma^2 = \omega_1\sigma_1^2 + \omega_2\sigma_2^2 + \omega_1\omega_2(\mu_1 - \mu_2)^T(\mu_1 - \mu_2)/2$$

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Results and Future Work

We achieve promising result close to ground truth in many cases. We also use Lee et al. [2008] to map Gaussian variance to two mip-map levels allowing environment convolution on the fly. However, a few problems occur with poorly represented lobes, like ghosting artifacts due to GSR subdivision and a failure to represent transmission lobes from sawtooth surfaces. Convolution also fails to shrink lobes for curved back surfaces (as in the globe). Future work includes carefully comparing our results with ground truth and making sure the same parameters produce similar images. We also plan to account for total internal refraction.

References

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