

Pre-Integrated Deferred Subsurface Scattering

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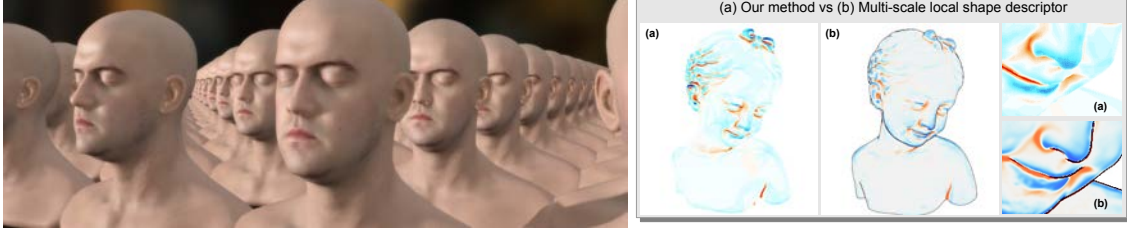


Figure 1: Left: Skin scattering using our method, showing its quality and scalability. 1650 × 1080 frames are rendered in 2.2ms on a NVIDIA GeForce GTX570. Right: Comparison between a) our curvature calculation method and b) previous work.

1 Introduction

For translucent materials such as human skin, milk and marble, light does not just bounce off the surface, but also penetrates the surface and scatters beneath. This is called subsurface scattering. [d'Eon and Luebke 2007]'s real-time texture-space diffusion method achieved high visual quality but not high performance or scalability. Screen-space subsurface scattering techniques [Jimenez and Gutierrez 2010] are more scalable but use a lot of memory, are expensive, and produce halo artifacts. We propose a scalable method called pre-integrated deferred subsurface scattering (PDSS) which adapts the forward-rendering pre-integrated skin scattering method [Penner and Borshukov 2011] (PSS) to screen space.

2 Our Approach

First we render the scene to G-Buffers, as in ordinary deferred lighting. Then we calculate curvature by taking central differences in world space. After this, we diffuse curvature and normals with a cross-bilateral filter. Then we calculate all the lighting similarly to PSS [Penner and Borshukov 2011], reusing curvature for ambient-occlusion. See Figure 2.

The novelty in our approach is our robust curvature estimation method. Previous methods for real-time curvature [Vergne et al. 2009] calculated curvature in screen-space, which produces artifacts due to division by zero at creases and silhouettes. We avoid these artifacts by calculating the world-space curvature instead (see Figure 1, right side).

The mean curvature is $\text{trace}(\nabla \mathbf{n}^t)/2$ where \mathbf{n}^t is the normal in the tangent space defined by the principle curvatures. Since the trace is invariant under the change of coordinate system it is sufficient to instead calculate $\nabla \mathbf{n}^w$ in world co-ordinates. We first calculate the local pixel-neighbour screen-space curvature, then chain-rule that to world-space before edge-aware diffusing it (see Eqn. 1. Apply

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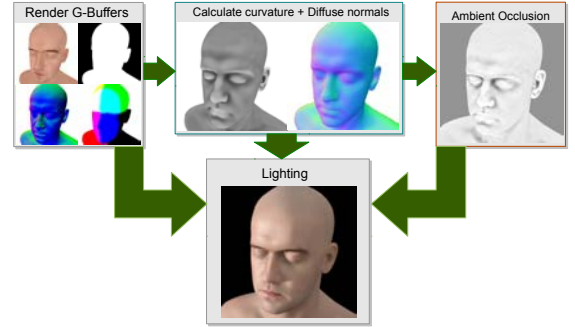


Figure 2: Overview of our PDSS method.

equation similarly for $\frac{\partial \mathbf{n}^w}{\partial y}$ and $\frac{\partial \mathbf{n}^w}{\partial z}$).

$$\frac{\partial \mathbf{n}^w}{\partial x} = \frac{\partial \mathbf{n}^w}{\partial u} \frac{\partial u}{\partial x} + \frac{\partial \mathbf{n}^w}{\partial v} \frac{\partial v}{\partial x} + \frac{\partial \mathbf{n}^w}{\partial w} \frac{\partial w}{\partial x} \quad (1)$$

Ambient occlusion may be estimated from curvature, using a curve-fitted polynomial to approximate the integration efficiently. Occlusion from multiple intermediate curvature blur passes may be combined to increase quality. Shading quality may be adjusted by performing curvature diffusion at different resolutions, and over different number of passes.

References

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