An Empirical Model for Heterogeneous Translucent Objects

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1 Scattering Model

Jensen et al. [2001] proposed to approximate multiple scattering in inhomogeneous materials by a set of coefficients for the dipole model per incident light position and a global modulation texture. This model however is not valid for imhomogeneous or geometrically complex objects.

Our basic model for subsurface light transport is based on their ideas but introduces two modifications. The behavior of multiple scattering is strongly dominated by the exponential fall-off of the intensity. We therefore propose to replace the dipole model by a sum of exponential functions. This approach improves modeling capabilities for heterogeneous material and allows to adapt to a more general surface geometry.

The standard dipole model assumes a rotationally symmetric behavior of the multiple scattering component. This is frequently inaccurate – e.g. for material with a preferred scattering direction or for heterogeneous material. We therefore introduce an *anisotropic model* and determine a set of parameters per direction between $\vec{x}_i$ and $\vec{x}_o$. For rendering, we blend between their contributions using a suitable weighting function $w_l(\vec{x}_i,\vec{x}_o)$:

$$R_d(\vec{x}_i,\vec{x}_o) = \alpha(\vec{x}_o)\cdot\sum_{l=1}^{m} w_l(\vec{x}_i,\vec{x}_o)\begin{pmatrix}1\\ s_g(\vec{x}_i)\\ s_b(\vec{x}_i)\end{pmatrix}\sum_{k=1}^{n} c_{kl}(\vec{x}_i)\cdot e^{d_{kl}(\vec{x}_i)|\vec{x}_o-\vec{x}_i|}. \quad (1)$$

$\vec{x}_i$ and $\vec{x}_o$ are the incoming and outgoing positions. The multiple scattering behavior is determined for each surface point and direction by the parameters c_k and d_k. In our experience, $n = 3$ is sufficient for most materials. Note that we have to ensure

$$R_d(\vec{x}_i,\vec{x}_o) \rightarrow 0 \text{ for } |\vec{x}_i - \vec{x}_o| \rightarrow \infty \quad (2)$$

for physically plausible behavior. Volumetric structures close to the outgoing position are modeled by the modulation texture $\alpha(\vec{x}_o)$.

2 Results And Discussion

For the first validation we acquired some planar samples of different materials (including different types of marble, a slice of an apple, and skin) using the DISCO setup from [Goesele et al. 2004]. Using only planar samples removes many possible sources of error and allows us to study the quality of the model. Figure 1 (right) shows the error of the reconstruction from our model with respect to the original data. The images show that we can model the object already quite accurately with the isotropic version of our model even in regions of great heterogeneity. The anisotropic version with 8 different directions reproduces the object almost perfectly.

We also acquired subsurface reflectance samples for real 3d objects with complex geometry. We then fitted parameters for the isotropic version of our exponential model per vertex.

Figure 2 also illustrates some problems with our approach. Note that the body of the alabaster pig appears too bright in our rendering. In real life we hardly see a substantial amount of intensity scattered through an object like this because the required contrast is not available. But we still notice the subtle effects at edges, shadow boundaries and in areas of thin material. We therefore believe that the proposed method is well suited for many real objects.

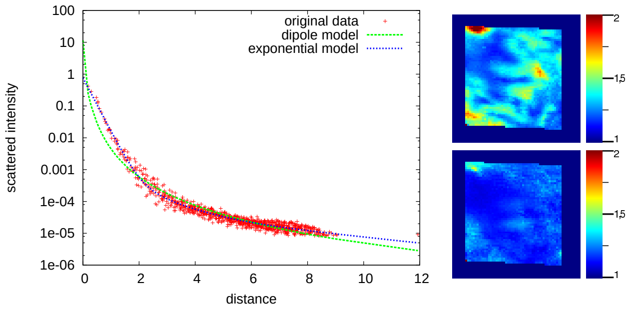

Figure 1: *Left:* Comparison of the fitting accuracy for measured input data. Note how close the exponential model approximates the data, especially in the region around the point of incidence where the dipole model starts off too high and falls too steeply. *Right:* Color coded reconstruction error for a planar sample of marble. The top image shows the error for the isotropic model, the bottom image for an anisotropic model with $m = 8$.

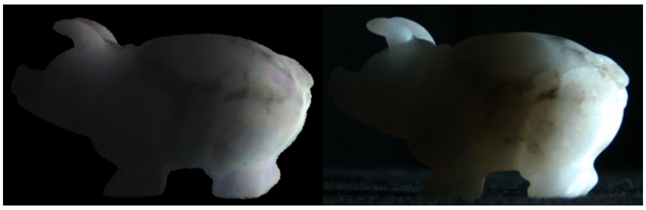

Figure 2: Comparison between a rendering of our model and a photograph of the real object under similar lighting conditions.

Effects close to the incident light position are faithfully modeled. Errors will mainly appear far away (and can even accumulate) – but will in most cases be hardly perceivable for practical scenes. The exponential fall-off and the modulation texture will however still yield a plausible behavior. Final models are small (typically on the order of 1 MB) and well suited for fast rendering.

References

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