An Empirical Model for Heterogeneous Translucent Objects

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Introduction

We introduce an empirical model for multiple light scattering in heterogeneous translucent objects. Motivated by the exponential fall-off of scattered intensity with distance, diffuse subsurface scattering is represented as a *sum of exponentials* per surface point plus a modulation texture. The parameters of this exponential model are then fitted to data acquired from real-life objects.

Sum of Exponentials

$$R_d(\vec{x}_i \rightarrow \vec{x}_o) = \sum_{k=1}^{n} c_k(\vec{x}_i) \cdot e^{d_k(\vec{x}_i)|\vec{x}_o - \vec{x}_i|}$$

- dipole model replaced by a sum of exponential functions
- function parameters determined per surface point using Levenberg-Marquadt optimization
- improved modeling capabilities for heterogeneous material
- model can be applied to more general surface geometry
- n=3 proved to be sufficient for most materials
- anisotropic version with parameters per surface point and scattering direction

$$R_d(\vec{x}_i \rightarrow \vec{x}_o) = \sum_{l=1}^{m} w_l(\vec{x}_i, \vec{x}_o) \sum_{k=1}^{n} c_{kl}(\vec{x}_i) \cdot e^{d_{kl}(\vec{x}_i)|\vec{x}_o - \vec{x}_i|}$$

Modeling Quality / Validation

- flat material samples to reduce amount of uncertainty
- sum of exponentials approximates measured input data much better than the dipole model
- anisotropic version improves modeling for highly heterogeneous material or material with a preferred scattering direction

Acquisition of 3D Objects

- we use the DISCO setup of Goesele et al. (SIGGRAPH 2004)
- illuminate individual surface points sequentially with a three-color laser
- record impulse response with a high-dynamic range video camera
- fit exponential parameters per vertex
- higher resolution modulation texture adds local detail

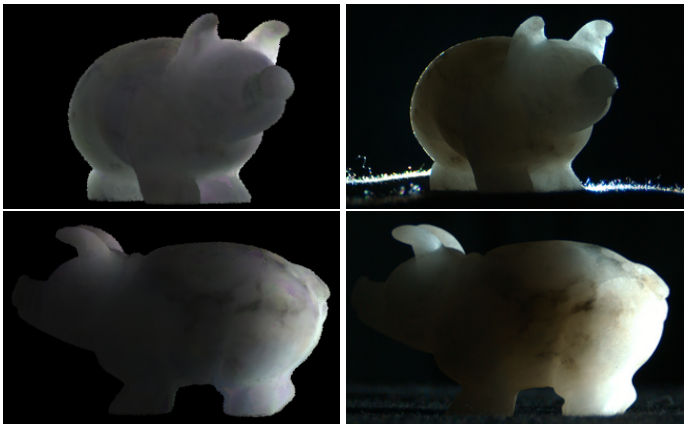

Figure 1: Comparison between renderings of our model (left) and photographs of the alabaster pig under similar lighting conditions.

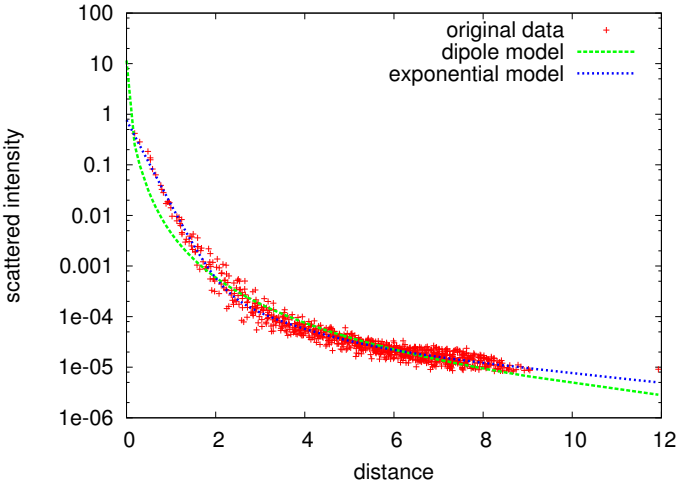

Figure 2: Comparison between dipole model and exponential model. The data corresponds to a single lit surface point in the marble example (Figure 3).

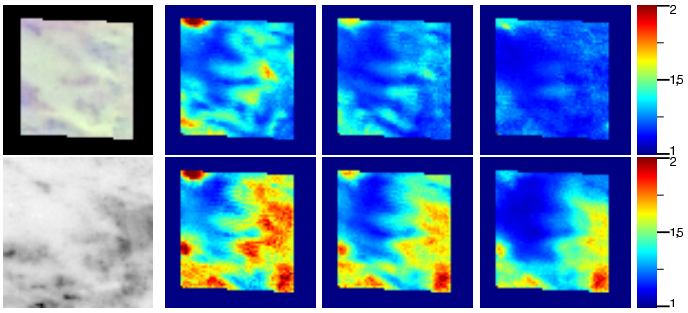

Figure 3: The marble example. *Left:* Modulation texture and diffusely lit surface. *Right top:* Reconstruction error for the exponential model. *Right bottom:* Error for the dipole model.

See MPI Technical Report MPI-I-2005-4-006 for details.