Render the Possibilities
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A Data-Driven BSDF Framework

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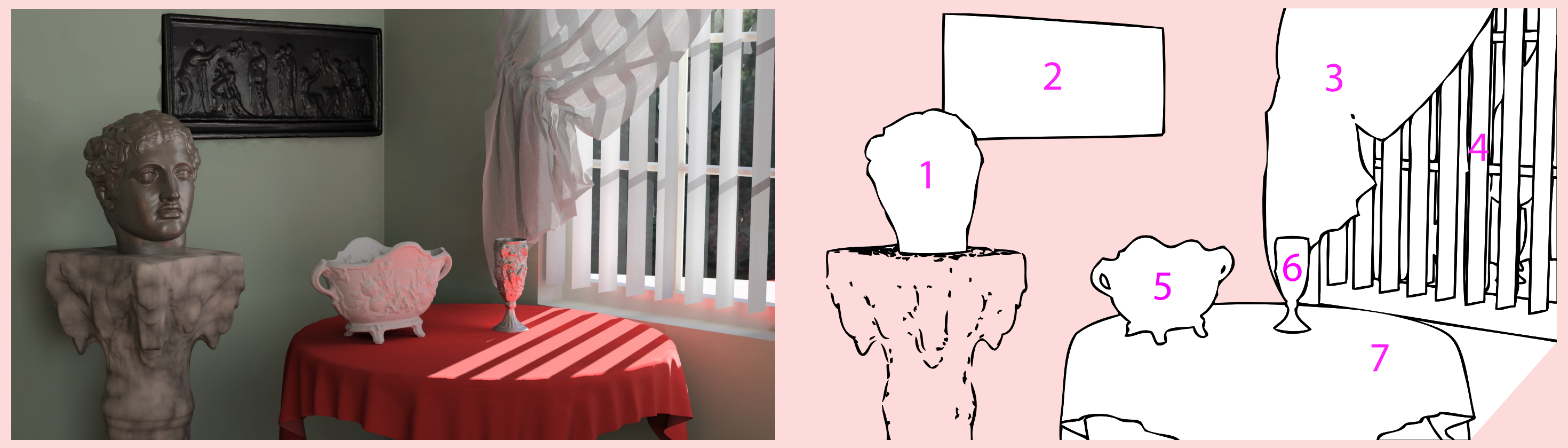
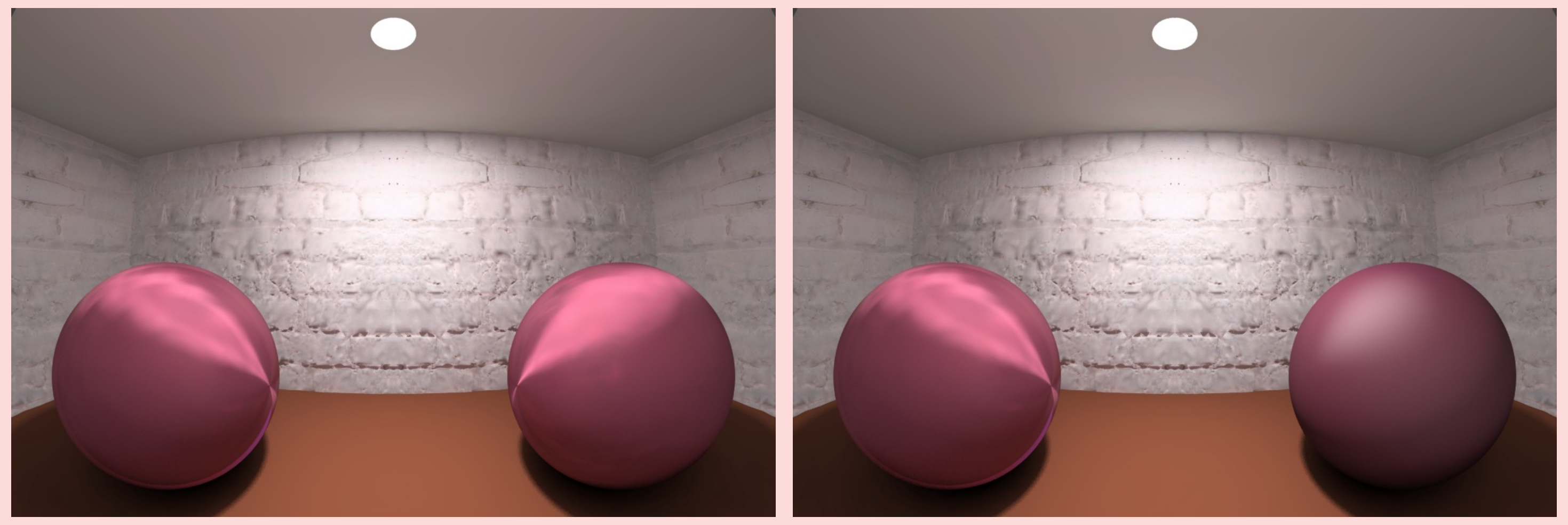
Abstract

We present a data-driven Bidirectional Scattering Distribution Function (BSDF) representation and a model-free technique that preserves the integrity of the original data and interpolates reflection as well as transmission functions for arbitrary materials. Our interpolation technique employs Radial Basis Functions (RBFs), Radial Basis Systems (RBSs) and displacement techniques to track peaks in the distribution. The proposed data-driven BSDF representation can be used to render arbitrary BSDFs and includes an efficient Monte Carlo importance sampling scheme. We show that our data-driven BSDF framework can be used to represent measured BSDFs that are visually plausible and demonstrably accurate.

Introduction



An image rendered using multiple data-driven BSDFs. (1) uses the alum-bronze material from the MERL dataset. (2) uses the anisotropic brushed-aluminum material from MERL. (3) uses a BSDF simulated from a detailed fabric model. (4) has a proxy BSDF (also simulated) that efficiently redirects light from the outside without affecting the appearance of the window itself. (5) uses the MERL alumina-oxide data, (6) uses the silver-metallic-paint material, and (7) uses the red-velvet anisotropic measurements [3].



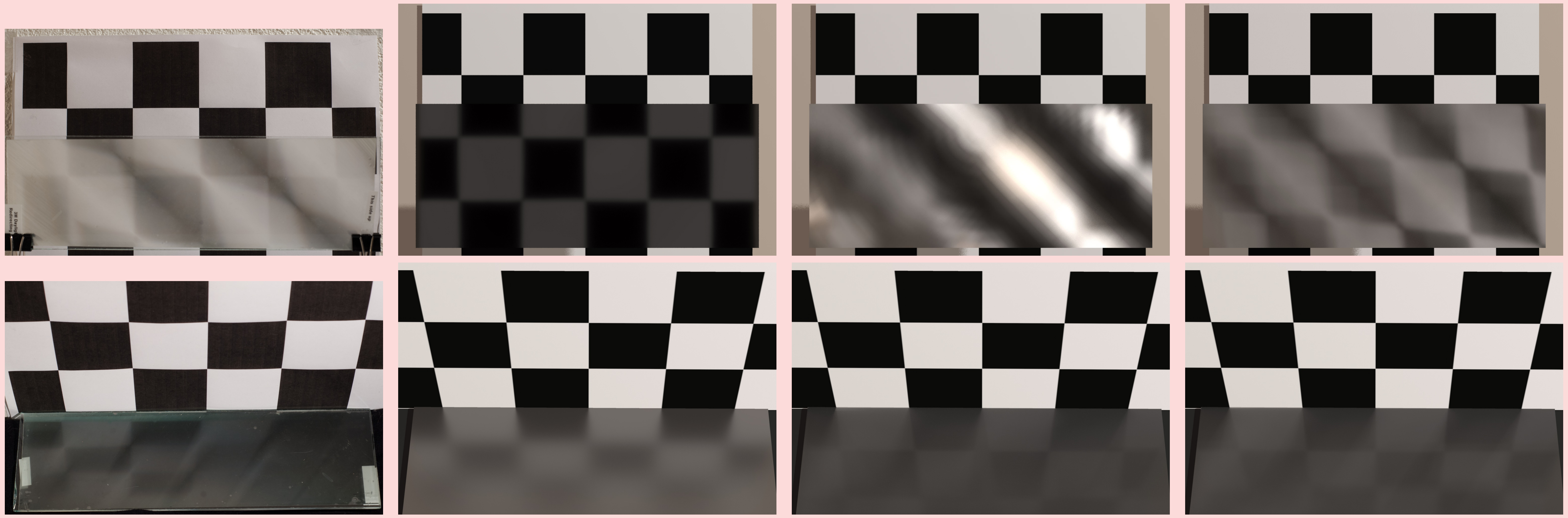
(a) (b)

(a) The measured anisotropic purple satin BRDF is interpolated into a rank-4 tensor tree and rendered by our data-driven BSDF representation (right). (b) The Ward BRDF model (right) does not fit the data nearly as well. The left ball in both images is the reference, rendered directly from measurements [3].

Optically thin, translucent materials are represented by Bidirectional Scattering Distribution Functions (BSDFs) in computer graphics. Although compact analytical BSDF models [2] for isotropic translucent materials exist, no comprehensive data-driven BSDF framework for both isotropic and anisotropic translucent materials has been presented. Such a BSDF framework is especially needed when material measurements do not fit the available analytical models. Making dense measurements is time consuming, particularly for anisotropic materials. Handling sparse measurements is a challenge since data-driven representations require dense measurements. In this work, we present a complete BSDF framework that reconstructs sparse measurements and represents arbitrary BSDFs. Our data-driven framework includes a tensor-tree BSDF representation [3] and an interpolation technique [4]. We compare our framework against ground truth and well-known representations, and show that our representation for measured BSDFs is accurate.

Our BSDF Representation

By using our interpolation, we generate $3D$ (i.e., rank-3 tensor) and $4D$ (i.e., rank-4 tensor) BSDF data for representing isotropic and anisotropic materials, respectively. Then, we represent this BSDF data using a "tensor tree" [3] which reproduces highly peaked data accurately and benefits from an efficient Monte Carlo importance sampling scheme. In this process, we use Shirley and Chiu's area-preserving map between our tensor-tree and the hemisphere, and a Hilbert traversal for efficient importance sampling. As seen in the following figure, our data-driven framework represents measured BSDFs accurately.

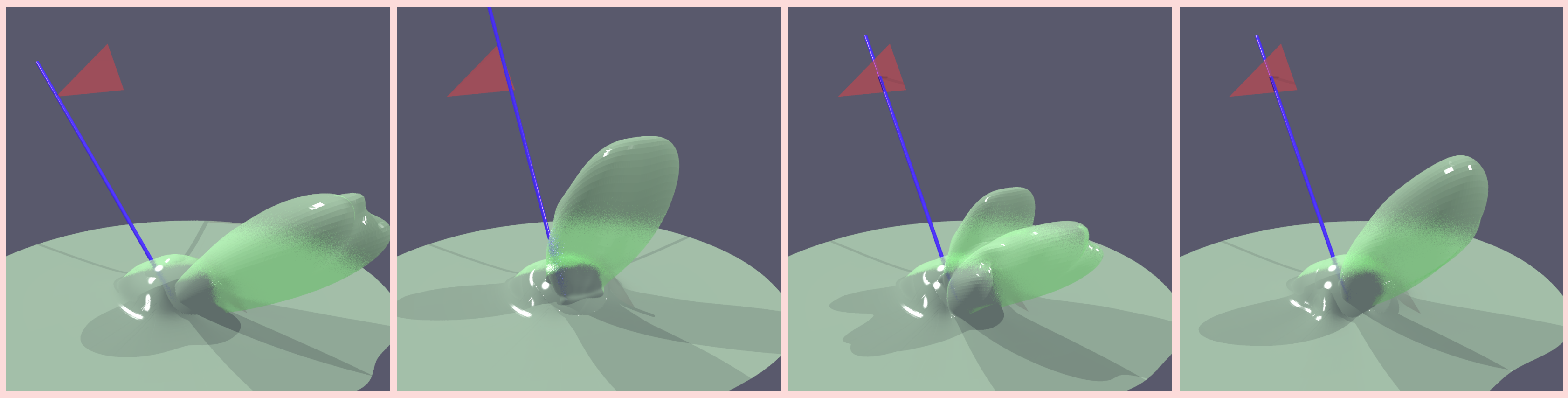


(a) Photograph (b) Walter et al.'s model (c) Linear interpolation (d) Our method

We qualitatively validate our BSDF framework (d) using a measured BSDF and two photographs (a). This translucent material is a daylight redirecting film (by 3M), shown at normal incidence to show light transmission (top row) and grazing angle for specular reflection (bottom). We compare with Walter et al.'s [2] BSDF model (b) and linear interpolation (c).

Our Interpolation Technique

Our technique [4] handles sparse, irregular BSDF measurements in three stages. First, we fit a sum of Gaussian lobes to the reflected BSDFs for each incident direction. Since each Gaussian lobe is a RBF, we call our sum of Gaussian lobes a RBS. Second, we construct a spherical Delaunay triangulation of the incident directions. Third, we compute a transport plan for shifting RBS in the first vertex to RBS in the second vertex for each edge of the triangulation [1]. We also use a method similar to nested linear interpolation of the transport plan for interpolating inside the triangles of this mesh as well. This technique allows us to interpolate between sparse incident directions, arriving at a continuous, complete, smooth description of the BSDF over the entire $4D$ BSDF domain.



(a) (b) (c) (d)

(a) Reflectance distribution for one incident measurement direction. (b) Distribution at another incidence. (c) Linear interpolation of three distributions. (d) Lagrangian mass transport.

References

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Funding & Contact

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