The D-BRDF model as a Basis for BRDF Acquisition

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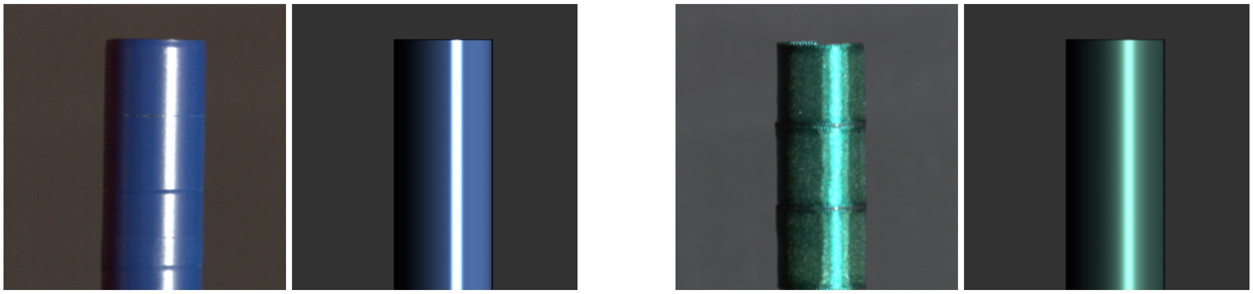

Figure 1: Visual comparison of D-BRDF fits of two kinds of acquired samples wrapped around a cylinder as lit by a point source against real photographs. In both the cases the D-BRDF fits were obtained by projecting just 25 basis images defined by the analytic model. Left column: Photographs of the samples. Right column: Rendering of the D-BRDF fits. Left pair: Blue electrical tape. Right pair: Green satin.

1 Introduction

Real world materials exhibit characteristic surface reflectance, such as glossy or specular highlights, and anisotropy that need to be modeled accurately for realistic rendering applications. The surface reflectance of a material is formalized by the notion of the Bidirectional Reflectance Distribution Function (BRDF). The acquisition of real world BRDF data, particularly with image-based techniques, has been a very active area of research over the last few years. Independent of the acquisition process, the acquired data is generally not used directly due to its large size, the noise present in the measurement process, and missing data for certain incident and exitant directions. Instead, the data is usually either fitted to an analytical model or projected into a suitable basis as a post-process. Recently, Ghosh et al. [2007] have proposed an alternative approach where the BRDF data is *optically* projected into a suitable basis function directly *during* the capture process. This speeds up acquisition time to one or two *minutes* compared to a few hours required by traditional approaches. They develop a set of basis functions for this purpose that are similar to the spherical harmonics basis and are orthonormal over the zone of directions that can be simultaneously covered with their optical setup.

While this zonal basis works well for low-frequency BRDFs, it suffers from ringing artifacts in the reconstruction for specular BRDFs. This is why Ghosh et al. propose to fit a higher order zonal basis measurement to the D-BRDF analytic model [Ashikhmin 2006] as a post-process. Given that an analytic representation is often used for rendering specular materials, it would be *optimal* to directly measure the response of such materials in a basis defined by an analytic model. This is what we propose to do in this work.

2 D-BRDF Basis

Most BRDF models are unfortunately not easily separated into a structured illumination and a reflected light basis, which presents a challenge for deriving the appropriate basis illumination. However, the D-BRDF model is an example of a model where such an illumination basis can constructed for measurements in the back-scattering direction. For the back-scattering direction, $\hat{k}_1 = \hat{k}_2 = \hat{k} = \hat{h}$ and the model simplifies to

$$\rho(\hat{k},\hat{k}) = \frac{c r_0 p(\hat{h})}{2(\hat{k}\cdot\hat{n}) - (\hat{k}\cdot\hat{n})^2}, \tag{1}$$

providing a function that is proportional to the distribution $p(\hat{h})$. Here c is a normalization constant and r_0 is the reflectance at normal incidence. We propose to model specular materials with the usual specular and diffuse separation $\rho(\hat{k_1},\hat{k_2}) = k_s \cdot \rho_{spec}(\hat{k_1},\hat{k_2}) + \frac{k_d}{\pi}$. Then the measurement process just involves obtaining estimates of the diffuse and specular reflectance coefficients k_d and k_s respectively with a basis of chosen distribution $p(\hat{h})$. An advantage of such an approach over using a linear zonal basis function is that the choice of basis is data-driven, thus making the encoding efficient.

We first project a constant basis $\frac{1}{\pi}$ over the measurement zone. The camera observes $k_d \cdot (\cos^2\theta_{min} - \cos^2\theta_{max})$ in response to this basis for a number of directions over the zone that we then compute an average of to obtain an estimate of k_d. In order to obtain an estimate of k_s, we sample the measurement zone at number of directions $\hat{k}$ with $\frac{cp(\hat{h})}{2(\hat{k}\cdot\hat{n})-(\hat{k}\cdot\hat{n})^2}$ as the basis and record $k_s \cdot \cos\theta \cdot r_0$. We estimate r_0 by observing the gain in reflectance at closer to grazing angles compared to normal incidence as suggested by Ashikhmin. Thereafter k_s can be estimated similarly from the multiple back-scattering direction measurements by computing averages of the measurements around each $\hat{k}$ weighted by the specular lobe in that direction. For the materials presented in Figure 1, we sampled the back-scattering direction at 24 uniformly distributed directions with the specular lobe basis. Hence, the D-BRDF fits to these materials were obtained with as few as 25 basis images compared to around 100 images with a higher order zonal basis measurement that would be required for similar specular materials. For the blue electrical tape material, we used a Phong lobe of exponent 300 as $p(\hat{h})$, while for the satin sample we used the satin distribution given in [Ashikhmin et al. 2000].

References

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