On-site Example-based Material Appearance Digitization

Yiming Lin
Imperial College London

Pieter Peers
College of William & Mary

Abhijeet Ghosh
Imperial College London

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

Figure 1: (a) An input HDR image of a red bowl placed along side a color checker chart. (b) The light probe of the surrounding room. (c) The red bowl's estimated diffuse spherical convolution. (d) A synthetic sphere rendered with the estimated BRDF parameters for the bowl's ceramic material. Insets show the reflection of the room window on the bowl and the sphere.

ABSTRACT

We present a novel example-based material appearance modeling method for digital content creation. The proposed method requires a single HDR photograph of an exemplar object made of a desired material under known environmental illumination. While conventional methods for appearance modeling require the object shape to be known, our method does not require prior knowledge of the shape of the exemplar, nor does it require recovering the shape, which improves robustness as well as simplify on-site appearance acquisition by non-expert users.

CCS CONCEPTS

• **Computing methodologies → Reflectance modeling**;

KEYWORDS

Material modeling, BRDF estimation, isotropic, uncontrolled lighting, unknown geometry.

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1 INTRODUCTION

In realistic digital content creation pipelines, artists often wish to closely match the appearance of virtual objects to the appearance of real world materials. Automating such a content creation process typically requires capturing physical reflectance properties of the desired materials. However, traditional reflectace acquisition approaches are expensive, time consuming and require dedicated setups hindering for adoption by non-experts. Riviere et al. [Riviere et al. 2016] recently proposed a convenient and accessible technique for on-site acquisition of surface reflectance of planar samples using a mobile device. However, their method still requires acquisition of a significant amount of data. In this work, we propose a novel example-based material appearance digitization technique that further reduces the amount of data required to just a single HDR photograph of an exemplar object. In addition, we do not require the exemplar to be planar or to even have a known shape which greatly simplifies acquisition for a non-expert user. Our method only makes modest assumptions on the underlying material and lighting; we assume the material can be described by a dielectric isotropic BRDF, with a possible texture-like appearance due to a repeating surface mesostructure, and that the incident lighting is uncontrolled, but dominated by a single bright region.

Closely related to our work is [Romeiro and Zickler 2010] in which a BRDF is estimated from a single image of an object with a *known* shape under *unknown* environmental illumination. However in practice, it is usually easier to acquire a light probe than it is to acquire the 3D shape of arbitrary non-planar objects. Recently, Aittala et al. [2016; 2015] proposed to estimate both the BRDF and a statistical model for visible surface geometry of exemplars. However, these approaches are limited to planar samples and controlled flash illumination. Instead, our approach is agnostic to the shape of the material exemplar while requiring just a single HDR photograph of the object (next to a color chart) under uncontrolled (but known) illumination in order to estimate the underlying BRDF.

2 METHOD

We assume that the exemplar object's appearance can be characterized by a dielectric material whose isotropic surface reflectance can be modeled using a microfacet BRDF [Cook and Torrance 1981]. Furthermore, we assume the main color in the observed reflection

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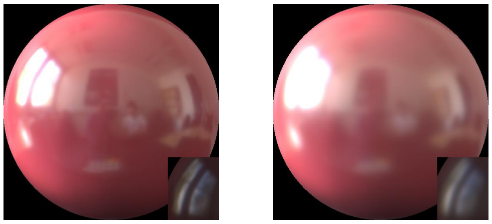


(a) Roughness 0.02 (b) Roughness 0.05

Figure 2: Two sample candidates after maximal intensity matching of renderings against photograph of the red bowl.

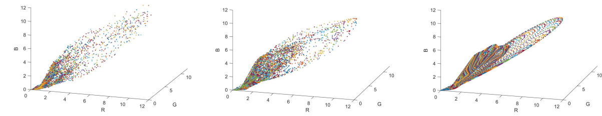
comes from the diffuse component. To white balance the acquired HDR photograph, we place a color checker chart next to the exemplar. Additionally, we employ a mirror ball to record a light probe of the surrounding environment. We also assume only one dominant light source in the environment and require it to not be incident at or near a grazing angle to avoid Fresnel gain in the observed reflection of the dominant light on the material exemplar.

2.1 Diffuse Estimation

Following the white balancing step, we select a frontal pixel in the image of the material exemplar with negligible specular reflection, and employ its RGB value as the diffuse albedo estimate. We then perform a diffuse convolution of the acquired environment map assuming a Lambertian BRDF with the estimated albedo. Figure 1c shows the diffuse estimation on a sphere for the red bowl exemplar shown in figure 1a.

2.2 Specular Albedo and Roughness Estimation

In the absence of known geometry, there is an inherent ambiguity between the specular albedo and the specular roughness of a material exemplar, as one of these parameters can be altered to compensate for the other along certain metrics, e.g. maximum intensity or spatial gradients. We observe that the Cook-Torrance BRDF acts as a Gaussian filter, i.e. it averages out the intensity and color of the dominant light source with its surrounding values in the light probe. The higher the specular roughness, the lower the intensity and the color variation in the observed reflection. We make the observation that while we can always alter the specular albedo to compensate for the low intensity, this would not affect the color variation on the sample. Based on this observation, we jointly tackle the problem of specular albedo and roughness estimation using a two-step approach. We pre-convolve the environment map with various values of specular roughness, ranging from 0.005 (i.e., mirror-like) to 0.4 (i.e., near diffuse), and find the corresponding specular albedos such that highest intensity on the simulated sphere is on par with the highest intensity seen in the image of the material exemplar. We next consider each of these pairs of specular roughness and albedo values as potential candidates (see Figure 2). Finally, we find the best matching candidate pair of parameter values by performing a global color profile matching in RGB space (see Figure 3).

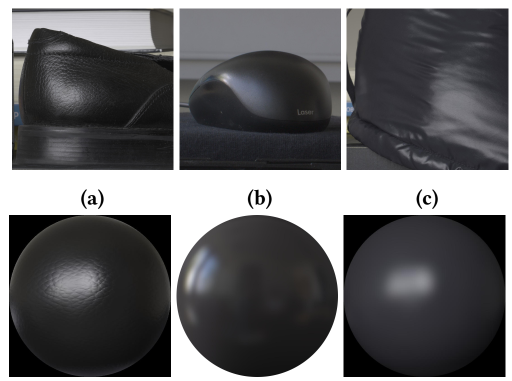


(a) (b) (c)

Figure 3: RGB space plot of pixels of: (a) the red bowl shown in figure 1a, (b) the rendered sphere shown in figure 1d, and (c) the rendered sphere shown in figure 2b.

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

Figure 4: A dark blue cup (a), and a green cup exemplar (c), and the corresponding estimated BRDFs (b, d).



(a) (b) (c)

(d) (e) (f)

Figure 5: Various exemplars exhibiting a rough surface mesostructure and corresponding estimated BRDFs. (a) Black leather shoe. (b) Plastic mouse. (c) Synthetic jacket.

3 RESULTS

Figure 4 presents additional results of appearance estimation using this approach for two exemplar objects (coffee cups) with a smooth surface. Finally, Figure 5 presents results for a few exemplars with a rough surface mesostructure.

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