Estimating Specular Roughness from Polarized Second Order Spherical Gradient Illumination

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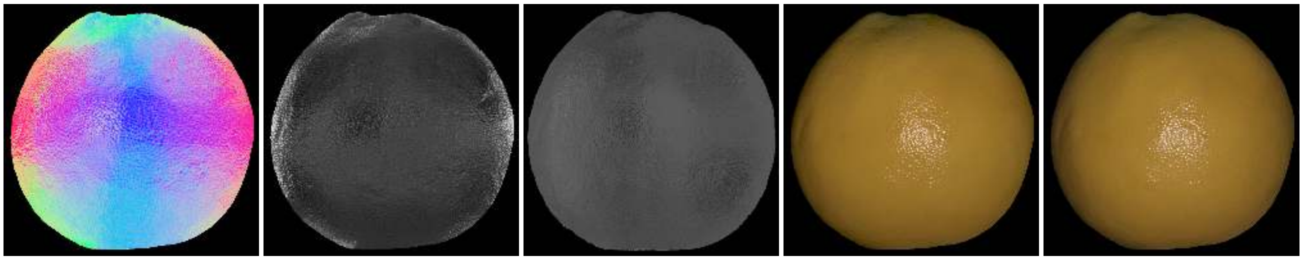

(a) specular normals (b) specular albedo (c) specular roughness (d) rendering (e) photograph

Figure 1: *Specular reflectance properties ((a)-(c)) of a plastic orange estimated using polarized second order spherical gradient illumination conditions. The estimated specular roughness map (c) is used as the per pixel distribution for a Torrance-Sparrow BRDF to create a rendering (d) that closely matches the validation photograph (e).*

1 Introduction

Measurement of spatially varying BRDFs of real world materials has been an active area of research in computer graphics with image-based measurements being the preferred approach in practice. In order to restrict the total number of measurements, existing techniques typically trade spatial variation for angular variation of the surface BRDF [Marschner et al. 1999]. Recently, Ma et al. [2007] introduced a technique for estimating high quality specular normals and albedo (Fig. 1, (a) & (b) respectively) of a specular object using polarized first order spherical gradient illumination conditions. In this work, we extend this technique to estimate per pixel specular *roughness* using polarized *second order* spherical gradients as a measure of the *variance* about the mean (reflection vector). We demonstrate that for isotropic BRDFs, only three spherical gradient illumination patterns related to the second order spherical harmonics are sufficient for a robust estimate of per pixel specular roughness (Fig. 1, (c)). Thus, we go further than previous work on image-based measurement of specular BRDFs that typically obtain sparse estimates of the spatial variation. Our technique also provides a direct estimate of the per pixel specular roughness and hence has the added advantage of not requiring any off-line numerical optimization that is typical of the measure and fit approach to BRDF modeling.

2 Acquisition

Our measurement setup consists of an LED sphere with approximately 150 individually controllable lights. Each light is covered with a linear polarizer in the pattern of [Ma et al. 2007]. Using this setup, we record an object's response to the spherical gradient illumination patterns of Ma et al., as well as three second order spherical gradients ($l = 2, m = \{0,1,2\}$). We record the illumination patterns in both cross and parallel polarization conditions in order to separate the diffuse and specular reflections. We then employ the polarization preserving (specular) components of the recorded photographs to estimate the per pixel specular reflectance properties.

3 Method

We model specular roughness as measure of variance (σ^2) about the mean (μ). In our case, μ is the view dependent specular reflection direction. The projected 0^{th}, 1^{st} and 2^{nd} order spherical gradient illumination patterns provide a measure of α, $\mu' = \int_\Omega \alpha \cdot x f(x) dx$, and $\mu'' = \int_\Omega \alpha \cdot x^2 f(x) dx$ respectively, where Ω is defined over a sphere of directions, $f(x)$ is the specular BRDF of the surface, and α is the specular albedo.

We employ these measurements α, μ' and μ'' to obtain an estimate of σ^2:

$$\sigma^2 = \int_\Omega (x - \mu)^2 f(x) dx. \qquad (1)$$

This provides us with an estimate of the per pixel specular roughness σ orthogonal to the mean direction. For isotropic BRDFs, we simply compute σ in any orientation orthogonal to the reflection vector. Finally, we transform the obtained per pixel specular roughness σ for the Torrance-Sparrow BRDF model using a look up table to generate our renderings (see Fig. 1).

4 Discussion

We restrict ourselves to isotropic BRDFs in this work. For anisotropic BRDFs, we would need to measure the response to all five second order spherical harmonics scaled to $[0,1]$. We also assume the BRDF to be symmetric about the mean direction. Higher order gradients would be required to measure asymmetries in the BRDF. Our technique is also limited by the lighting resolution of the apparatus used for spherical illumination. Our LED sphere has 20 lights around the equator which imposes an upper limit on the number of frequencies that can be resolved with such discrete lighting. Hence, our setup works well in practice for glossy BRDFs.

References

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