Cosine Lobe Based Relighting from Gradient Illumination Photographs

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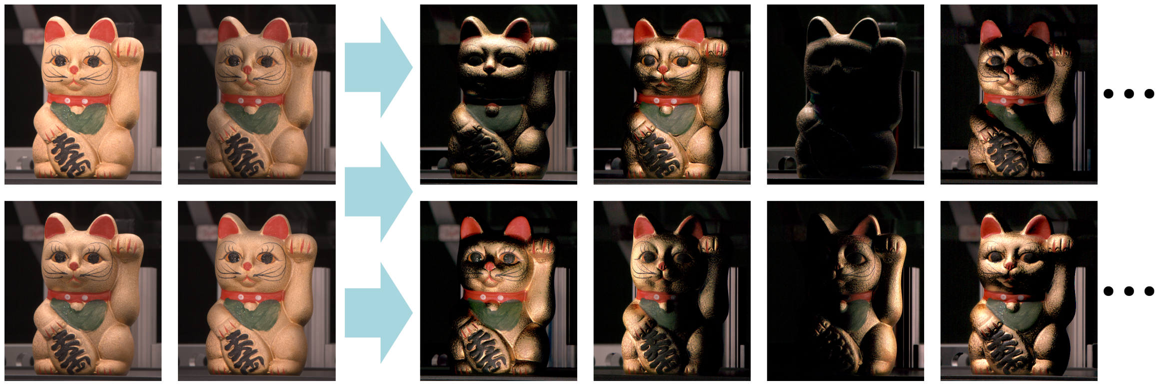

Figure 1: *Relighting from four photographs: Cosine lobes are fit to the reflectance function at each pixel and then relit with a point light. Left: uniform and gradient illumination input photographs; Right: relit images under some example point light illumination conditions.*

1 Introduction

Image-based relighting is a powerful technique for synthesizing images of a scene under novel illumination conditions, based on a set of input photographs. While successful relighting methods exist, they either require many photographs [Debevec et al. 2000], or operate on a limited class of materials or illumination conditions [Ma et al. 2007][Ramamoorthi 2006].

We present an image-based method for relighting a scene by analytically fitting a cosine lobe to the reflectance function at each pixel, based on gradient illumination photographs. An acceptable fit can be obtained for many materials using a single, colored cosine lobe, which is obtained from just two color photographs: one under uniform white illumination and the other under colored gradient illumination. For materials exhibiting wavelength-dependent scattering distributions, a better fit can be obtained using an independent cosine lobe for each of the red, green, and blue channels, which is obtained from three monochromatic gradient illumination conditions instead of a single colored gradient condition, requiring a total of four photographs.

2 Method

We photograph the scene inside a geodesic sphere of colored LED lights, which can be programmed to produce gradient illumination as well as uniform white illumination, similar to [Ma et al. 2007]. We compute the mean spherical angle of reflected light α from the ratio images of the gradient illumination photographs to the uniform illumination photograph, and we compute the total amount of reflected light I from the uniform illumination photograph, as in [Ma et al. 2007]. If a single colored gradient is used instead of separate x, y and z gradients, we make the assumption that the ratio images are wavelength-independent. Unlike [Ma et al. 2007], we do not estimate normals or albedo from these quantities, but instead take them as measured properties of the reflectance function itself. Further, we make use of the additional information contained within the denominator in the normalization step of computing the mean spherical angle. This allows us to solve for an additional parameter in the reflectance function, which in our case is the exponent n of a cosine lobe reflectance function.

We explore two different cosine lobe reflectance functions, which integrate easily over the uniform and gradient illumination conditions, so that an analytic solution for the fit is obtained. Cosine lobes of the form $k \max(0, \alpha \cdot l)^n$ with $k = \frac{1}{2\pi} I(n+1)$ work well for diffuse and specular materials, but fail for materials with broader scattering such as fur. An alternative form $k(\frac{1}{2}\alpha \cdot l + \frac{1}{2})^n$ with $k = \frac{1}{4\pi} I(n+1)$ works well for broad scattering and still produces visually plausible results for diffuse and specular materials.

3 Results

The method works well whenever the reflectance function is well approximated by a single smooth lobe. Results for highly specular materials are noisy, due to the hardware limitation of using LED lights to approximate continuous illumination. Ground truth comparisons confirm that effects due to non-smooth reflectance functions are not reproduced, such as hard shadows, but even with these limitations the method produces visually plausible results with no disturbing artifacts over a wide range of materials and illumination. Furthermore, the results are more consistent with ground truth than those obtained from using the input photographs as a linear basis.

References

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