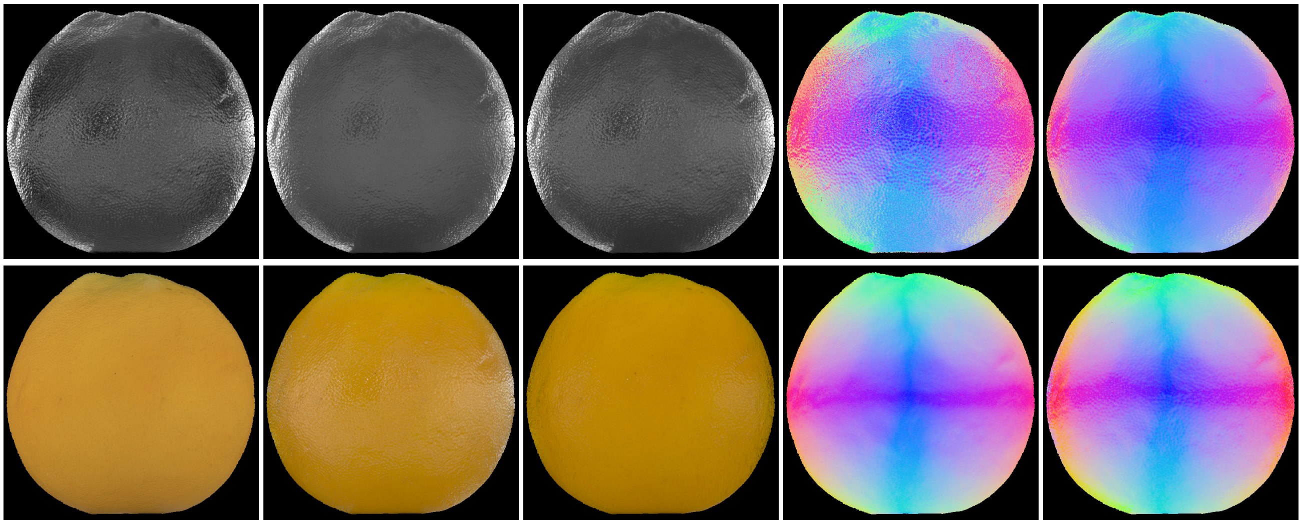
Data-Driven Diffuse-Specular Separation of Spherical Gradient Illumination

Tongbo Chen Abhijeet Ghosh Paul Debevec
USC Institute for Creative Technologies



(a) true albedo (b) initial separation (c) final albedo (d) true normals (e) separated normals

Figure 1: *Diffuse-specular separation of a plastic orange captured under spherical gradient illumination. Top-row: specular separation. Bottom-row: diffuse separation. (a) & (d): Polarization-based separation. (c) & (e): Data-driven separation.*

1 Introduction

Separation of the diffuse and specular components of observed reflectance has been an active area of research in computer graphics and vision, with major applications in reflectance modeling and scene analysis. Traditionally, researchers have investigated diffuse-specular separation under point or directional illumination conditions while employing polarization and, in the case of dielectric materials, color space analysis techniques. Recently, Ma et al. [2007] introduced a technique for estimating high quality diffuse and specular normals and albedo maps (see Fig. 1, (a) & (d)) of a specular object using polarized spherical gradient illumination. However, the employed polarization technique imposes view-point restriction, and results in insufficient light levels for performance capture with high speed acquisition. Hence, in this work, we look into an alternate diffuse-specular separation technique for spherical gradients based on a data-driven reflectance model. Traditional separation techniques based on color space analysis focus on removing specular reflections from the observation for scene analysis [Mallick et al. 2005]. In contrast, we focus on obtaining high quality estimates of both the diffuse and the specular reflectance components.

2 Method

We propose a diffuse-specular separation technique based on a data-driven model of diffuse and specular reflectance of spherical gradient illumination. We build this model from example data with known ground truth diffuse-specular separation. We use polarization based separation as ground truth data in this work. Note that we do not require observation of the exact same object to build our reflectance model, only an object with similar diffuse and specular relectance characteristics. Our separation algorithm proceeds in two stages: First, we employ the example data with known ground truth separation to build orientation-based reflectance profiles for diffuse and specular reflectance under the uniform spherical illumination condition. Thereafter, we employ the diffuse and specular reflectance profiles to split the uniform illumination observation into diffuse and specular albedos (Fig. 1, (b)). Note that these reflectance profiles capture the increased specular reflection at grazing angles due to Fresnel reflectance. We use the unseparated gradients to compute the surface normals for this initial separation.

The above separation (b) serves as an intial guess for the following iterative optimization: We relight the separated diffuse and specular albedo into the X, Y and Z gradient illumination conditions, sum them up and then compare to the observed unseparated gradients. The error in the relit conditions are attributed alternatingly to the specular normal estimate and to the specular albedo estimate in subsequent iterations. We repeat the above normal and albedo update for a few iterations until convergence.

3 Acquisition and Results

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 in both cross and parallel polarization conditions in order to obtain what we consider to be the ground-truth diffuse-specular separation of albedo and surface normals. We then employ our example based data-driven separation on the parallel polarized images in order to compare the proposed separation technique (see Fig. 1, (c) & (e)) with the polarization-based result.

References

MA, W.-C., HAWKINS, T., PEERS, P., CHABERT, C.-F., WEISS, M., AND DEBEVEC, P. 2007. Rapid acquisition of specular and diffuse normal maps from polarized spherical gradient illumination. In *Rendering Techniques*, 183–194.

MALLICK, S. P., ZICKLER, T. E., KRIEGMAN, D. J., AND BELHUMEUR, P. N. 2005. Beyond lambert: Reconstructing specular surfaces using color. In *Proc. IEEE Conf. Computer Vision and Pattern Recognition*.