# Dichromatic Separation: Specularity Removal and Editing (sketches_0668)

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The reflectance of a wide variety of materials (plastics, plant leaves, glazed ceramics, human skin, fruits and vegetables, paper, leather, etc.) can be described as a linear combination of specular and diffuse components, and for many applications we can benefit from separating an image along these lines. Figure 2, for example, depict a photo-editing application in which visual effects are simulated by independently processing separated diffuse and specular image layers. Similarly, specular/diffuse separation plays an important role for image-based modeling applications in which diffuse (specular-free) texture maps are sought.

Applications such as these rely on our ability to separate the specular and diffuse components of an image. This is an ill-posed problem, however, and in the past its solution has required the manual identification of highlight regions (e.g., [Tan et al. 2003]), the use of special acquision systems (e.g., polarizing filters), or restrictive assumptions about the scene (e.g., untextured surfaces). Recently, we have introduced a method for specular/diffuse separation that overcomes many of these limitations [Mallick et al. 2006], and in this sketch, we build on this work, showing how it can be used for specular editing. We present results on high-quality images and video acquired in the laboratory in addition to images taken from the Internet. Results on the latter demonstrate robustness to low dynamic range, JPEG artifacts, and lack of knowledge of illuminant color.

## 1 Approach

As in most existing techniques for specular/diffuse separation, our approach is based on exploiting color differences between specular and diffuse reflections as described by Shafer's dichromatic model. According to this model, the color of the specular component at each surface point is the same as that of the illuminant ($S$), while the color of the diffuse component depends on the spectral reflectance of the surface and can changes from point to point.

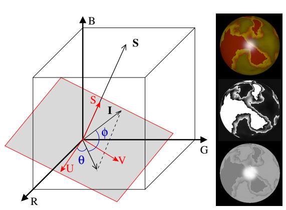


Figure 1: Left: SUV color space. Right-top An RGB image. Right-center: $\theta$ image. Notice that $\theta$ is free of shading and specularity. Right-bottom: $\phi$ image. $\phi$ is free of shading, but encodes the specular component of the image.

We begin with a partial specular/diffuse separation obtained by a rotation and reparameterization of RGB color space. As shown on the left of Fig. 1, the rotation aligns one of the color axes (red, say) with $S$, the known source color, and we define the angular quantities $\theta$ and $\phi$ in this rotated space. The advantages of this $(\theta,\phi)$ representation of color are two-fold. First, as shown on the right of the figure, $\theta$ is independent of both specular reflection and diffuse shading effects and therefore provides uncorrupted surface color (i.e., spectral reflectance) information. (We refer to this angle as "generalized hue" since it reduces to the standard definition of hue when the illuminant is white.) Second, the angle $\phi$, which is also independent of the diffuse shading effects, isolates the dimension of color space in which diffuse and specular mixing occurs.

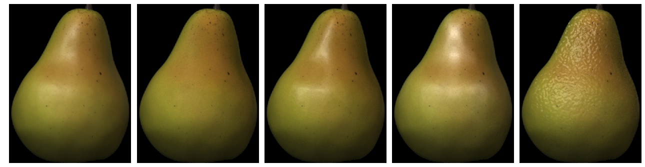

Figure 2: Specular editing from a single input image. Left to right: input, specular-free, sharpened, re-lit, and 'wrinkled'.

Given this representation, the problem of specular/diffuse separation reduces to one of separating the specular and diffuse contributions to the $\phi$-image. To accomplish this separation task, we share color information across the image through a series of local interactions. Intuitively, a reasonable estimate of the unknown diffuse contribution to $\phi$ at a point in a specular region (the center of the sphere in Fig. 1, for example) is obtained from a nearby specular-free point with the same generalized hue. Formally, the diffuse contribution at each point of the $\phi$-image is obtained by modeling the $\phi$-image as a discrete approximation of a continous 2D signal and evolving a non-linear PDE

$$\phi_t = -\left(\nabla\phi^\top \mathrm{M}(\theta)\nabla\phi\right)^{1/2}, \qquad (1)$$

that computes the multi-scale erosion [Brockett and Maragos 1994] of the 2D signal. Here, the matrix $\mathrm{M}(\theta)$ determines the shape of the structuring set for the erosion process, enabling the sharing of diffuse color information without smoothing texture boundaries. In textured regions, for example, diffuse color information is shared in all directions and the required structuring set is disk-shaped. In textured regions, however, the required structuring set is linear and aligned with the iso-contours of $\theta$. Finally, the same equation extends naturally to the case of videos, where erosion is performed along iso-surfaces of $\theta$ in three-dimensional space-time.

Figure 2 shows representative results in which the specular/diffuse separation is computed as described above (without manual intervention), and the two layers are edited and recombined to produce a variety of visual effects. Additional results on images are videos are provided in the accompanying movie.

## References

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