On the Appearance of Translucent Edges

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Translucency is a common visual phenomenon. It occurs whenever light penetrates a material and scatters within it before re-emerging toward the observer. This internal scattering can create a variety of image effects, depending on an object's shape and material; its distance from the observer; and the composition of the lighting around it. Common human experience suggests that these image effects contain useful material information, and there is psychophysical evidence that humans can discriminate subtle differences in translucent appearance, recognize translucent material categories, and make inferences about physical scattering parameters [1, 2, 3, 4].

There ought to be specific patterns of image brightness, or their statistics, that constrain the set of plausible shapes and materials in an image of translucency. If we understood these patterns, we could use them to develop inference algorithms, analogous to those that exist for opaque scenes.

One prominent class of brightness patterns is edges, or sharp local changes in image brightness. Edges have a variety of causes—cast shadows, material boundaries, occlusions, etc.—and models of edges play prominent roles in a variety of inference algorithms, including contour detection, deblurring, and material recognition. In this paper, we focus on edges that are caused by a discontinuous change in surface orientation, such as at the corners of the cubes in Figure 1. Locally, this geometry can be modeled by the one-dimensional *wedge*. We use this as an archetypal configuration for studying edges of translucency.

The radiance profile observed from an opaque wedge would be the familiar step function, which is a popular edge model in image processing and computer vision. But the radiance profiles for translucent wedges are very different. As shown in Figure 1, they tend to exhibit multiple extrema in the vicinity of an orientation discontinuity, and these extrema are often displaced away from the geometric discontinuity.

The physical causes of these profile phenomena are not well understood. One reason is that they are hard to describe analytically. For the translucent wedge configuration, radiance profiles represent the combination of interface reflection with various orders of volume scattering events. They result from interactions between view and light directions, refractive index, optical density, scattering albedo, and scattering phase function. There is unlikely to be an analytic solution to the radiative transport equation for this scenario, and we have yet to find a useful approximate solution.

Our strategy is to explore these phenomena empirically through simulation. Using Monte Carlo rendering techniques, we generate a database of thousands of radiance profiles for many scattering materials and wedge configurations. We catalog the variety of profiles we observe, and identify characteristic features of translucent edges, such as qualitatively distinct regions and displaced local extrema discussed above, that distinguish them from edges of opaque materials. A typical example is shown in Figure 2. We then explain how these features arise, by analyzing light transport in terms of interface events, single-scattering, mid-order scattering, and high-order scattering (diffusion). Additionally, we explain the effect of the various material and geometry parameters on the appearance of the profiles, and identify specific classes of "material metamers": different materials that produce similar or identical edge profiles. Finally, we show that these characteristic features are robust to the various non-idealities of real-world wedge geometries, indicating that they can be computed from photographs of real translucent objects.

Our comprehensive description of the distinguishing features of translucent edge profiles and their relation to underlying geometry and material parameters provides a foundation for investigating how these profiles can be used for computer vision tasks involving translucent materials. Tasks that can benefit from our study include material-aware edge localization and edge classification; deblurring and denoising with material-aware priors; material recognition using statistics of edge profiles; and shape and material inference using translucent versions of photometric stereo and shape from "shading" algorithms.

This is an extended abstract. The full paper is available at the Computer Vision Foundation webpage.

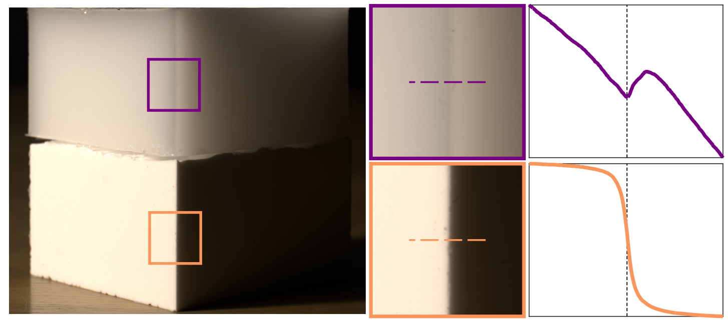

Figure 1: Radiance profiles at a discontinuity in orientation. The *wedge configuration* is a horizontal cross-section of two planar faces that meet in a vertical line. Here it is lit from the left. If the material were opaque (as below) the profile would be a step edge. When it is translucent (as above), the profiles can be very different, with extrema displaced from the discontinuity.

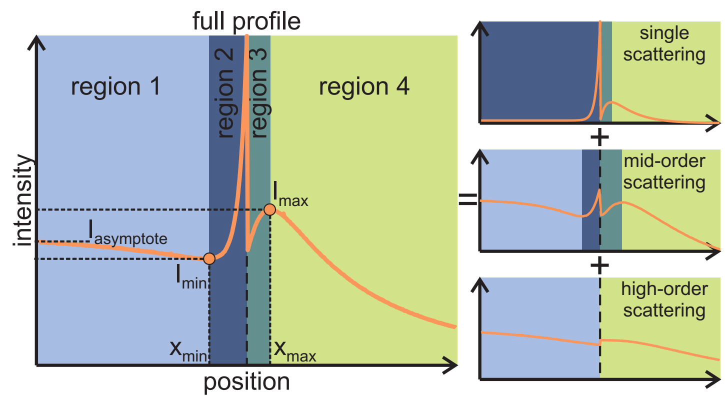

Figure 2: Left: An edge radiance profile for a translucent material is typically made up of four qualitatively distinct regions. These give rise to characteristic features such as local radiance extrema away from the geometric edge. Right: Decomposition of the profile into single, mid-order, and high-order scattering components. Different subsets of the four qualitative regions of the full profile appear in the three scattering components.

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