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Through a Glass Brightly: Material Appearance and Image Quality

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ABSTRACT

Images have always presented a puzzle for perceptual scientists because they serve as visual representations of objects while also being objects themselves. Much effort has gone toward understanding how images represent the three-dimensional properties of objects, and there is now considerable knowledge about the relations between the geometric projections used in image rendering and the perceived shapes of depicted objects [1]. Considerably less effort has focused on how images convey other important object properties such as materials and textures [2], and although there is a vast literature on image quality that purports to speak to these issues [3], the premise of this project is that much this work is misguided because it conflates the idea of images as signals with the idea of images as messages.

Efforts to increase image quality typically focus on improving the signal coding capabilities of the medium (resolution, frame rate, dynamic range, color gamut, etc.), with little regard for the messages (visual information) that the images will be used to communicate. The faith is that if the image signal is ideal then the message will be conveyed with high fidelity. This approach seems logical and has mathematical support from the fields of signal processing and information theory, however the danger of focusing exclusively on the signal properties of images is that we may miss insights and opportunities that come from distinguishing between the imaging medium and the visual messages conveyed by that medium.

Figures 1 illustrates the distinctions can be drawn between the signal and message properties of images. The left panel shows a grayscale photograph of a black sports car parked on a concrete pad. Both the car and the pad show distinct reflections of the surrounding environment that suggest that the car is glossy and the concrete pad is wet. The grayscale levels and contrasts in the image also suggest that the car is black (or a dark color) and the concrete pad has a lighter shade. The right panel shows the same scene represented by a halftoned image created to simulate the contrast and sharpness of a typical newspaper print. This image is clearly different than the one on the left, and in conventional terms one would say that its quality is low. However, as a visual representation of the scene, this image is largely equivalent to the one on the left in that we can still perceive important properties of the depicted objects such as the shape, reflectance, and gloss of the black car, and the reflectance and gloss/wetness of the concrete pad.

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Figure 1. Signals and messages in imaging: Left) High quality grayscale image of a glossy black car on a wet concrete pad. Right) Halftoned, printed, and rescanned version of the image on the left. Note that while the visual "quality" of the image on the right is lower, its ability to represent important scene properties such as the shape, color, and finish of the car is largely the same as the image on the left.

We are currently conducting a program of research to investigate the visual system's ability to "see through" image distortions such as the ones shown in Figure 1 to perceive the object and scene properties the image depicts [4,5]. In a series of experiments we are investigating the ability of conventionally low quality (low contrast, blurry, disordered) images to faithfully represent the material properties of objects. Our approach is to perform gloss scaling experiments using images of glossy objects and to compare the scales produced by high and low quality images. Figure 2 shows examples of some of the images being used in the experiments.

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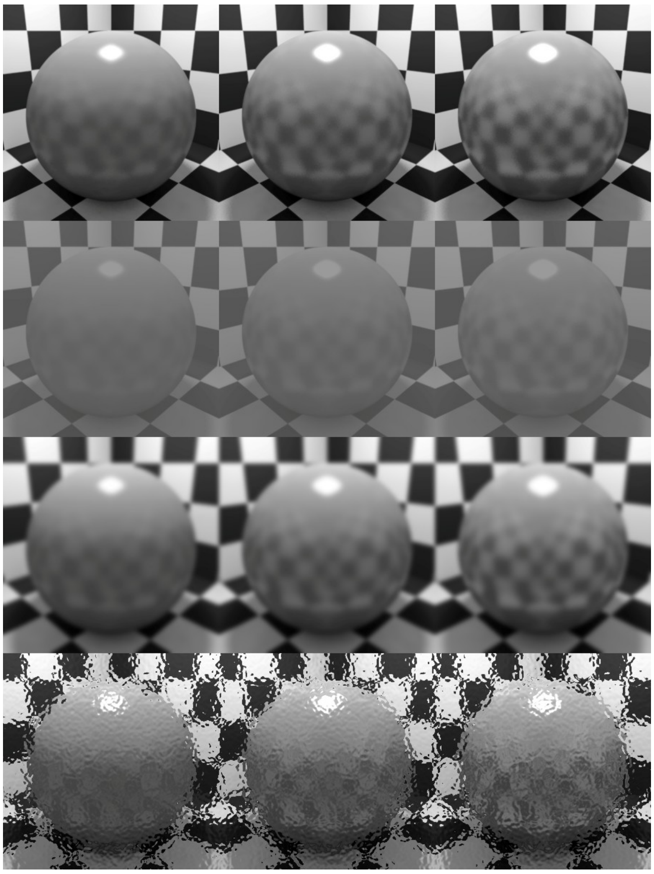

Figure 2. Example stimuli being used in the gloss scaling experiments. Top row: reference images showing gray spheres with three levels of contrast gloss. Second row: reference images with contrast reduced by 70%. Third row: references images blurred by a three-pixel wide Gaussian kernel. Bottom row: reference images disordered using the Photoshop "textured glass" filter. Note that while the image rows are clearly different from each other, the apparent gloss differences between the spheres in each row is not much affected by the different treatments.

In pilot studies, contrary to the predictions of standard image quality metrics, we are finding that the ability to discriminate objects with different gloss properties is not much reduced by these distortions. It is as if observers are able to see through the distortions to correctly perceive the material properties of the depicted objects. On the basis of these experiments we are developing new image quality metrics that take into account recent findings on the role of light reflection statistics in material perception [6,7], and analyze interactions between the statistics of light structuring by materials and the statistics of image coding distortions.

The focus of this work is on understanding the relationships between the characteristics of image signals and the fidelity of the visual messages images convey. Our goals are to learn more about how images work as visual representations, to develop more meaningful image quality metrics that better predict how well images with different signal properties serve as visual representations of the objects they depict.

Categories and Subject Descriptors

I.3.7 [**Three-Dimensional Graphics and Realism**]: Color, shading, shadowing, and texture.

General Terms

Algorithms, Measurement, Experimentation, Human Factors.

Keywords

Material appearance, image quality, visual perception

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