Luminance re-mapping for the control of apparent material

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1 Introduction

We can visually estimate surface properties of natural objects, not only colour and lightness, but also glossiness, translucency, and softness. How does the human brain accomplish this job? Considering the fact that the image of a surface is a result of highly complex optical process including reflection, refraction, and scattering, one may think that the estimation of surface properties should involve deep, complex neural computations including 3D shape reconstruction. However, psychophysical evidence suggests that the perception of some surface qualities uses shallow and simple computations based on simple statistics or features in the 2D image. For example, Beck [1] have pointed out that the presence of highlights in the surface image is a strong cue for the perceived glossiness. Our recent analysis demonstrated that the perceived lightness and glossiness of a natural surface strongly depend on skew in the luminance histogram of the image [2, 3].

Is this also true for the other surface properties such as translucency and metallicity? In optics, translucent objects generally have strong scatterings of the light inside the material, and metallic ones a larger amount of mirror reflections than diffuse reflections. As a result, these materials exhibit specific patterns on the surface image distinct from those of the other materials in complicated ways. It seems difficult to describe key image features for those properties. However, we here demonstrate that a simple re-mapping of the image luminance can dramatically alter the perceived material.

2 Demonstrations

Figure 1 shows a luminance re-mapping to make an opaque object translucent. First, separate an object image into diffuse and specular components (here we used a computer-generated BRDF image, Fig. 1a, to do it easily). When the luminance contrast of the diffuse component was reversed by a negative slope function (Fig. 1b) while the specular part kept intact, the object looks translucent like gelatine (Fig. 1c); Fleming et al. [4] also showed that altering the histogram of a semi-translucent object could alter its translucency. Fig.2 shows another re-mapping to make metallic surfaces. When the luminance of the diffuse component of the original image was re-mapped through a wavy (e.g., sinusoidal) function, which produces sharp bright-dark lines along the original shading patterns, the object looks metallic. If one took an advantage of the fact that the specular part (highlights) tend to have the highest luminance in the image, the same effect could be obtained without separating diffuse and specular components; e.g., reversing the contrast except the highest luminance range can make the object look translucent. The method can be further extended to produce more complex materials such as human skin. As shown in Fig. 3, for example, when the blurred version of the opaque image, which mainly conveys coarse shape information of the object, was overlapped with the translucent image, the object appears to have a wet, soft, skin-like surface.

3 Conclusions

The luminance re-mapping of the 2D image could be a cheap and quick tool for the material control in graphical design. Moreover, it suggests that human material perception may be based on simple 2D image cues, since the resulting image is not physically correct. Detailed analysis of the results of luminance re-mapping suggest that a mismatch in the direction/location between highlights and shading may be a cue for translucency, and that sharp repetitive lines along the side of the object contour may be a cue for metallic appearance. Interestingly, these cues resemble tricks that have been employed by painters to quickly draw those materials. For scientific understanding more than an art, however, it would be necessary to define those cues mathematically in terms of image statistics. In this respect, it is worthwhile to note that the orientation distribution of luminance gradients in the image (orientation fields [5]), as well as the perceived shape of the object, is relatively constant before and after material transformation, whereas the bright-dark polarity of luminance gradients changes a lot. Human visual system may utilize these relationships to estimate surface properties.

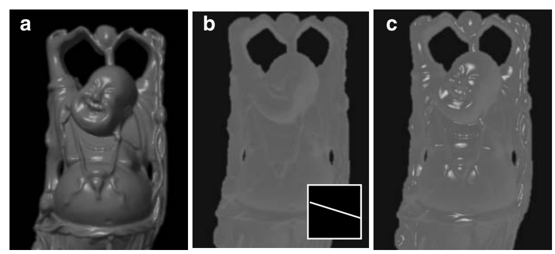

Figure 1 Luminance re-mapping for translucent surfaces. Inset is a look-up table between (a; diffuse part) and (b).

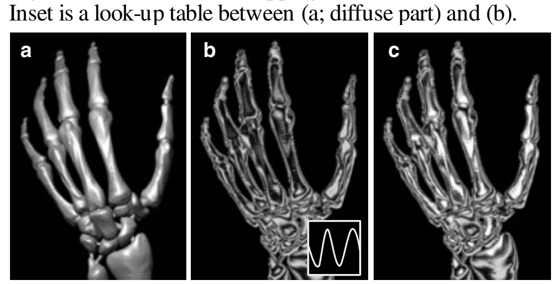

Figure 2 Luminance re-mapping for metallic surfaces.

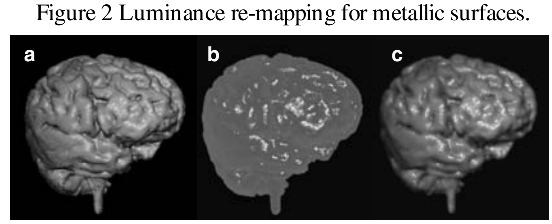

Figure 3 (a) Original image. (b) Translucent object made by luminance re-mapping. (c) The sum of (b) and the blurred version of (a; diffuse part).

References

[1] Beck (1975), Sci. Am. 233, 62-75. [2] Motoyoshi et al. (2005), VSS 2005. [3] Motoyoshi et al. (2005), ECVP 2005. Fleming et al. (2004) APGV 2004. Fleming et al. (2004), J. Vision, 798-820.