Shadow Removal from a Real Image Based on Shadow Density

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1 Introduction

Shadows are physical phenomena observed in most natural scenes. Since shadows and shades enhance the reality of images, many works on shadowing and shading have been done for realistic image generation. Shadows, however, often poses difficulties when using real images in image synthesis, because shadows imply the geometric relationship between objects, light source, and viewpoint. This means that real images including shadows are used for image synthesis only in a limited situation where the lighting condition is consistent with that of the real images [Sato et al. 1999].

This paper proposes a method to remove shadows from a real image based on the shadow density, which is defined as a measure of brightness. Using the shadow density, the image is segmented into several regions that have the same density, Then, we remove the shadows by modifying the brightness and color [Baba and Asada 2003]. Finally we show the experimental results of shadow removal in real images.

2 Shadow Removal Algorithm

Assuming that objects are lit by direct and ambient lights, and shadows consist of umbra and penumbra regions. The brightness E of a point on the object surface is represented by

$$E = (kI_d \cos\theta + I_e)R_d \quad (1)$$

where θ denotes the angle between the incident light direction and the object surface normal, I_d and I_e are the luminances of direct and ambient lights, respectively, and R_d is the reflectance of the object surface. $k\,(0 \leq k \leq 1)$ is the attenuation factor of the direct light; that is, $k = 1$ means the object point is in a sunshine region and $k = 0$ is in an umbra one.

Because an image has a texture, it has a variety of reflectances. If we segment the image by the brightness, regions do not represent the effects of the attenuation factor k of equation (1). So, we apply some sort of filter to the original image. After applying a maximum value filter and a minimum value filter, we apply a smoothing filter to get the global brightness of the image. From the global brightness, we calculate the shadow density s which shows the degree of the light effect. It becomes 0 in a sunshine region, and it becomes 1 in an umbra region. By using the shadow density, we segmented the shadow area into small regions as shown in figure 1.

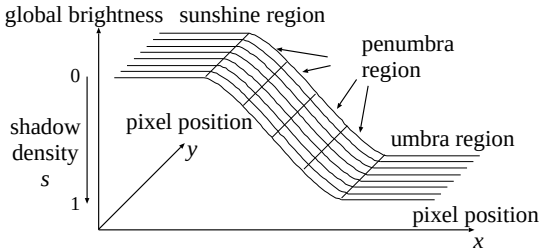

Figure 1: A shadow model consisting of sunshine, penumbra and umbra regions.

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Once the image is segmented into sunshine, penumbra and umbra regions, we can remove the shadow by performing color and brightness adjustment for penumbra and umbra regions[Baba and Asada 2003]. Since the lighting color of the umbra region is not always the same as that of the sunshine one, we perform the color adjustment between them. Then, the color average and variance of the umbra region are adjusted to be the same as those of the sunshine one. In penumbra, color and brightness adjustments for small regions are performed the same as they are for the umbra region.

3 Experimental Results

Figure 2 shows examples of shadow removal from outdoor scene images. The left column shows the original color image, the center is the gray-scale image of shadow density, and the right is the result of the shadow removal. These results show the effectiveness of the proposed method for images with single texture.

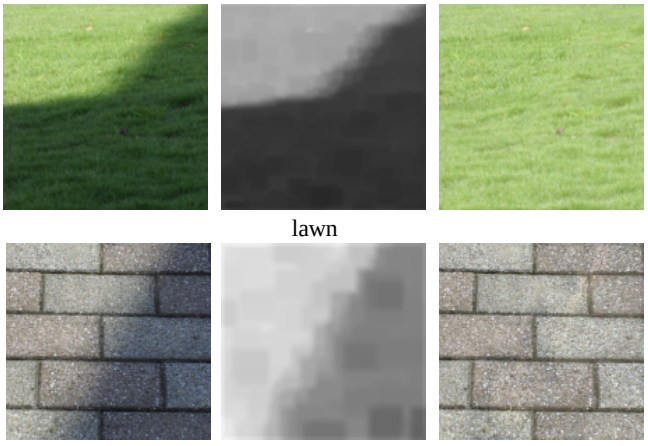

Figure 2: Experimental results of shadow removal from real images.

4 Conclusion

This paper describes a shadow removal method from a real image based on shadow density. Our algorithm worked successfully in shadow removal for single texture images. In the future, we will improve the method so that it can be applied to images with multiple textures.

References

BABA, M., AND ASADA, N. 2003. Shadow removal from a real picture. In *Proceedings of the SIGGRAPH 2003 conference on Sketches & applications*, ACM Press, 1–1.

SATO, I., SATO, Y., AND IKEUCHI, K. 1999. Illumination distribution from brightness in shadows: Adaptive estimation of illumination distribution with unknown reflectance properties in shadow regions. In *ICCV (2)*, 875–882.