連続フレーム画像を用いた反射パラメータの推定法

Estimation of Surface Reflectance Parameters from Image Sequence

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1. Introduction

Object reflectance properties are very important information in order to acquire object model for computer graphics applications. Most of techniques separate diffuse and specular components first and then compute the reflectance properties [1]. However, the separation has many problems. In this report, we estimate the reflectance properties of real 3D object without separation by applying an iterative method to fit reflectance data to Torrance-Sparrow reflection model. It is certain that the diffuse and specular components can be separated using the estimated reflectance properties. The experimental results demonstrate the effectiveness of proposed approach.

2. Reflection Model

The most general reflection model in computer vision and computer graphics applications is represented by linear combination of diffuse component and specular component. Torrance-Sparrow model [2] is used for reflectance parameters analysis in this report.

$$\begin{aligned} I &= K_d (L \cdot n) + K_s \exp(-\alpha^2 / 2\sigma^2) \\ &= m_0 \sin\varphi_L \sin\theta_L + m_1 \cos\varphi_L + m_2 \sin\varphi_L \cos\theta_L + m_3 \exp(-(\frac{m_4 - \theta_n}{m_5})^2) \end{aligned} \tag{1}$$

Here L is light source direction and n is the normal of a 3D point on object surface. K_d and K_s are diffuse and specular reflectance. θ_L is the angle between the projection of light source on horizontal plane and view direction and θ_n is the angle between the projection of normal on horizontal plane and view direction. What we need to estimate are the parameters m_i ($i = 0,1,\cdots 5$). After all parameters are estimated, the reflectance properties of this point on 3D surface of object can be computed from these estimated results. It is also possible to compute the normal vector of this point.

3. Estimation of Reflectance parameters

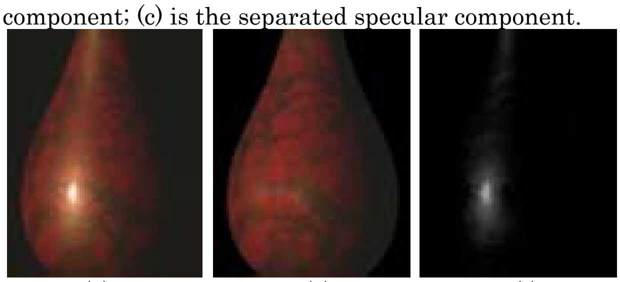
In our experiment, an object was put on a rotary table under a light source with known direction. The image sequence was taken using a camera with fixed position and direction. The intensity values of correspondent pixels on each image for all points on 3D object were sampled by applying modeling method. These data are used for fitting Torrance-Sparrow model (1). Since this model is non-linear model, Levenberg-Marquardt method is employed to minimize following fitting error:

$$E = \sum_k \left(I(\theta_k; m_0, m_1, m_2, m_3, m_4, m_5) - I_k \right)^2 = \sum_k e_k^2 \tag{2}$$

For estimating the parameters in (2), the initial guess is needed. The initial values of first 3 parameters are the value at a position located far enough from specular peak values. m_3 is the value of specular peak. m_4 is the location of specular peak. m_5 is given with an empirical value 0.08. With 4 or 5 iterations, all parameters can be computed. After the reflectance properties are estimated, the computation of the diffuse component and specular component is a nontrivial problem. Note that the unit normal vector of a 3D point on object surface can also be computed from the estimated parameters.

4. Experimental Results

We have used the proposed approach to the simulated data and data acquired the real image sequence taken under a light source with known direction by a fixed camera. The experimental results are effective and applausive. Figure 1 (a) shows one of original image in an image sequence; (b) is the separated diffuse component; (c) is the separated specular component.



(a)　(b)　(c)

Figure 1. Original image (a); separated diffuse component (b) and specular component (c).

5. Conclusion

One of key features of the proposed approach is that we estimate reflectance properties before separation to eliminate error produced during separation; another feature is that we estimate all parameters at the same time without knowing body color and light source color, which makes the proposed approach more stable and effective. In our future work, multi-light source will be considered.

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