二つの点光源を用いた物体反射成分の分離

Separation of Surface Reflection Using Two Point Light Sources

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1. Introduction

We had proposed an approach for separating diffuse and specular components from 3D object illuminated by one point light source [1]. However, with only one light source, we can't avoid shadows hindering some process such as matching for shape modeling. Illumination with multiple light sources help for matching, but the reflection separation will remain a problem. In this report, we will challenge this problem to compute reflectance properties and to separate diffuse and specular components from reflection of a 3D object illuminated with two point light sources, by applying an iterative method to fit reflectance data to Torrance-Sparrow reflection model. The tentative experimental results demonstrate the effectiveness of proposed approach.

2. Reflection Model

While the object is rotating on a rotary table, the view direction and two point light sources are remained fixed. The camera and rotary table are well calibrated, so we can obtain the intensity variation data of 3D point. The intensity variation is fitted to a reflection model. With multiple illuminations, a simplified Torrance-Sparrow model [2] is used for reflectance parameter analysis:

$$I = I_d + I_s = K_d \sum_{i=1}^{n} (L_i \cdot N) + K_s \sum_{i=1}^{n} \exp\left(-\alpha_i^2 / \sigma^2\right) \quad (1)$$

Here L_i is light source direction which is assumed to be known, and $n=2$ is the number of light sources. And N is normal of a 3D point on object surface. Parameters K_d and K_s are diffuse and specular reflectance, α_i is the angle between normal vector and the bisector of view direction and each light direction and σ represent the roughness of surface in a small area. For simplicity, we use polar coordinates to express each vector. With simple arrangement mathematically, using polar coordinates of light source direction vectors, view direction and normal vector, equation (1) can be rewritten in the form of (2):

$$\begin{aligned} I_d &= A\sin\theta + B\cos\theta + C \\ I_s &= D_1 \exp\left(-\left(\frac{E_1-\theta}{F}\right)^2\right) + D_2 \exp\left(-\left(\frac{E_2-\theta}{F}\right)^2\right) \end{aligned} \quad (2)$$

where θ is the rotation angle of turntable, other parameters are induced from equation (1) using several mathematical operations.

3. Separation of reflection

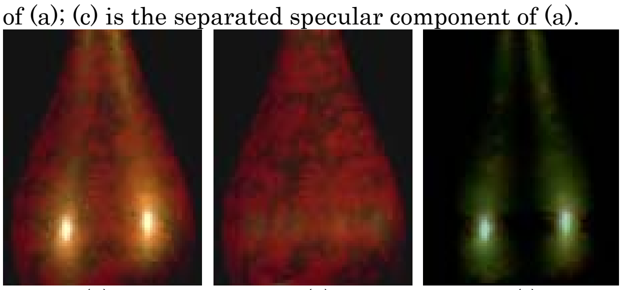
Before separating reflection components for each 3D point, we need to estimate numerically the parameters in equation (2). Since the reflection model is a non-linear model, Levenberg-Marquardt method is employed to minimize following fitting error:

$$E = \sum_k \left(I(\theta_k; A, B, C, D_1, E_1, D_2, E_2, F) - I_k\right)^2 = \sum_k e_k^2 \quad (3)$$

For estimating the parameters in (2), the initial guess is needed. The initial values of first 3 parameters are the values at a position located far enough from two specular peak positions. Since there are some noises in the raw data, some cautions should be paid for finding the peak values and peak locations. Low pass filter is a good tool for solving this problem. Roughness F 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 diffuse and specular components are computed using these parameters.

4. Experimental Results

We have used the proposed approach to the simulated data and data acquired from the real images of object illuminated with two light sourced with known direction by a fixed camera. Figure 1 (a) shows one of original images; (b) is the separated diffuse component of (a); (c) is the separated specular component of (a).



(a) (b) (c)

Figure 1.

One of key features of the proposed approach is that the reflection with two illuminants can be separated. Moreover, estimating reflectance properties first can alleviate errors produced during separation; another feature is that we estimate all parameters at the same time without knowing body color and light source color. The improvement of the algorithm and the multiple light sources are under our investigation.

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REFERENCES

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