Luminance Distribution Control
based on the Separation of Direct and Indirect Components

Osamu NASU Shinsaku HIURA Kosuke SATO
Graduate School of Engineering Science, Osaka University
1-3 Machikaneyama-cho, Toyonaka, Osaka 560-8531 Japan
{shinsaku,sato}@sys.es.osaka-u.ac.jp

Abstract We propose a method to control the luminance distribution on a scene by modeling the light propagation with direct and indirect components separately. To reduce the measurement time and amount of data, we incorporate geometric locality of direct component and the narrow spatial bandwidth of indirect component into the light transport model. Since the luminance distribution of the scene for the given illumination pattern is reproduced quickly and precisely, we can compensate the illumination pattern to generate the required luminance distribution of the scene without actual projection.

1. Introduction

Description of the scene using the linear model of light transport is useful to represent the relationship between the projection pattern and luminance distribution of the scene. The luminance distribution (or image taken by a camera) can be represented by an equation $c = Tp$ where p is a intensity distribution of projector pixel and T light transport matrix. However, it is impractical to measure the matrix T by naively turning on each pixel of the projector at once (brute force method), because the cost of time and storage is very expensive as shown in Table 1. Therefore, we have proposed a fast and efficient method[1] to measure the light transport by separating direct and indirect component of reflected light[2]. In this paper, we show an improvement of this method with an application of this light transport model to control the luminance distribution of the scene.

2. Proposed Method

We represent the light transport of the scene with an equation $c = T_d p + T_i R p$ where T_d and T_i are the light transport of direct and indirect component, respectively. Since the bandwidth of indirect component is limited to lower spatial frequency, we cau use downsampling matrix R. To measure T_d, we use periodic dot patterns as shown in Figure 1. We also use vertical and horizontal Gray code pattern to acquire the geometric relationships between projector and camera pixels, and we can determine which pixel of the projector affects to each observed pixel because the effective area of direct component is limited around the geometrically corresponding pixel. For measuring the indirect component, we use overlapped cosine pattern as shown in Figure 2. For both processes, we used the method proposed by Nayar et al.[2]. Figure 3 shows the estimated luminance distribution for given projection pattern. Our method is not only fast and efficient but also precise because the indirect component is so weak to capture with ordinary camera and single pixel projection.

Table 1. Cost for light transport acquisition and luminance distribution estimation.

	Proposed	Brute Force
Number of Projection Pattern	12,313	786,432
Amount of Data	1.87GB	1.86TB
Number of Multiplication	1.2×10^9	6.2×10^{12}

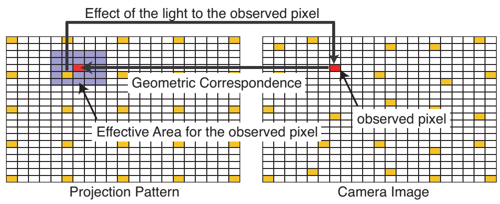

Figure 1. Projection pattern to measure the direct component.

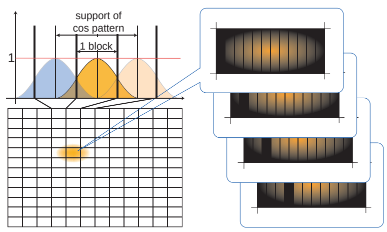

Figure 2. 2-D cos pattern to measure the indirect component.

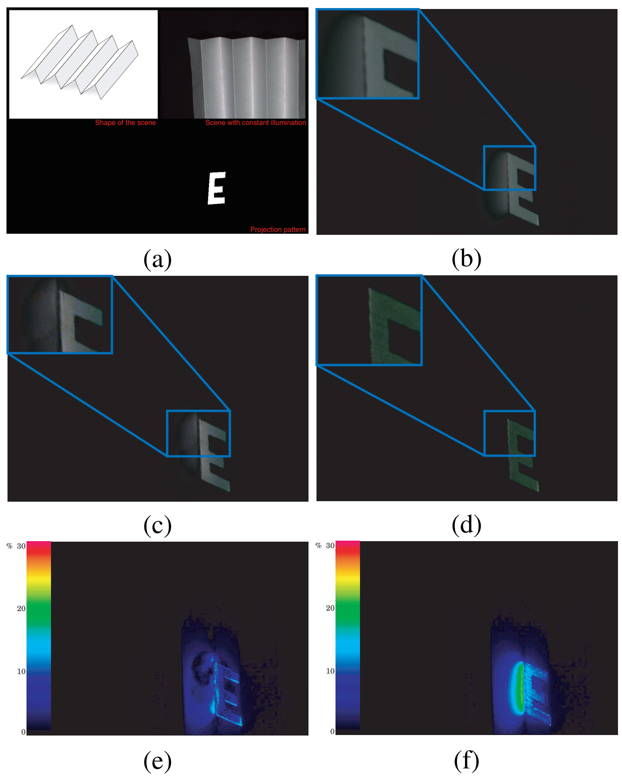

Figure 3. Estimation of the luminance distribution. (a) Scene for experiment and projected pattern, (b) Luminance distribution by actual projection, (c) Estimation by proposed method, (d) Estimation by brute-force method, (e) Residual error of proposed method $|(b)-(c)|$, (f) Residual error of brute-force method $|(b)-(d)|$.

Once we can estimate the luminance distribution of the scene for given projection pattern, we can calculate the compensated projection pattern which produces required luminance distributions by using feedback control without actual projection.

3. Results and Conclusion

Figure 4 shows a result to control the luminance distribution of the scene with interreflection to uniform. We found the calculation of projection pattern converges within 5 iterations. Figure 5 shows the application of coloring the object. The interreflection on the floor is clearly compensated with our method. Downsampling of the indirect component measurement not only approximates the scene well but also solves the issue of dynamic range of the camera and projector.

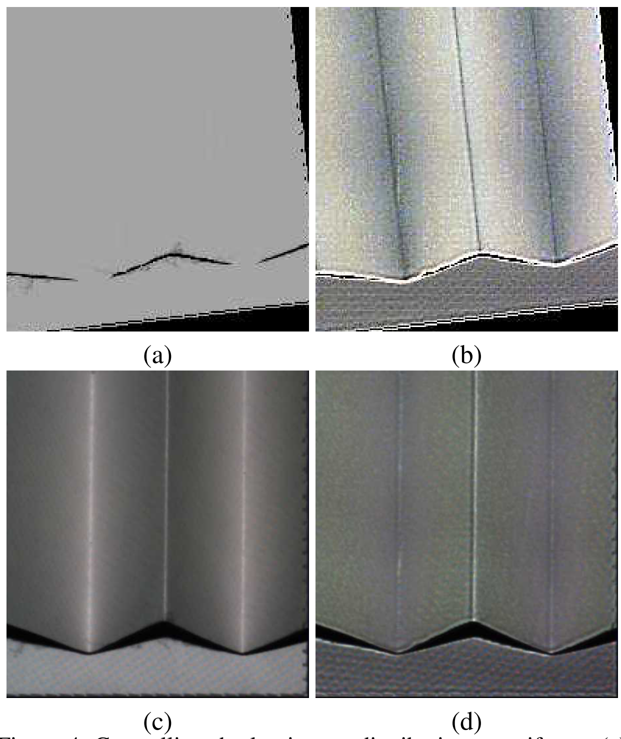

Figure 4. Controlling the luminance distribution to uniform. (a) Initial projection pattern, (b) final projection pattern after 5 iteration, (c) Initial luminance distribution with pattern (a), (d) Final luminance distribution with pattern(b).

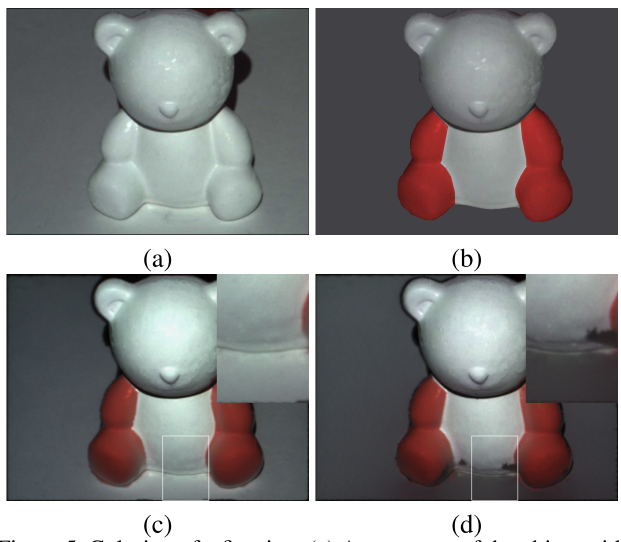

Figure 5. Coloring of a figurine. (a) Appearance of the object with uniform projection, heavy interreflection effect is seen on the floor, (b) Goal image, (c) luminance distribution without compensation, (d) Compensated luminance distribution with proposed method.

References

[1] O. Nasu, S. Hiura, and K. Sato. Analysis of light transport based on the separation of direct and indirect components. *PROCAMS/CVPR2007*, pages 1–2, 2007.

[2] S.K.Nayar, G.Krishnan, M.Grossberg, and R.Raskar. Fast separation of direct and global components of a scene using high frequency illumination. *Transaction on Graphics,vol.25, no 3, pp.935-943*, 12(1):234–778, 2006.