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

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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 $c = Tdp + TiRp$ where $Td$ and $Ti$ 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 $Td$, 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.

![Figure 1. Projection pattern to measure the direct component.](image1)

![Figure 2. 2-D cos pattern to measure the indirect component.](image2)
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.

### References
