Luminance Correction with Raw Digital Images

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1 Introduction

In recent large-scale multi-projector displays, luminance correction techniques using digital cameras inevitably contribute to offering seamless image projection. However, in order to acquire the characteristics of the cameras, they require troublesome estimation processes or expensive photometers which are manually placed and slow in measuring a large number of points on projected images. Therefore, in this research, we propose a simple and efficient luminance correction technique using raw digital images taken only with a high-end digital camera.

2 Proposal technique

[Majumder and Gopi 2005] shows an abstract modeling function that describes the color seen by a viewer when displayed by a general display device including a projector. Based on this model, luminance is the most effective factor to provide seamless image projection. For any other input $i_l(l = R, G, B)$, the luminance contribution of channel l, $D_l(s,t,i_l)$, is shown as

$$D_l(s,t,i_l) = h_l(i_l)(W_l(s,t) - B(s,t)) \quad (1)$$

where $0.0 \leq h_l(i_l) \leq 1.0$, $W_l(s,t)$ is the maximum of the luminance projected at projector coordinate (s,t), and $B(s,t)$ is the *black offset*. Since h_l does not vary spatially, h_l is expressed as a function of i_l only, and called the *transfer function* for channel l. To obtain h_l, the previous approaches use a photometer for measuring the relationship between input i_l and observed luminance. Although the photometer is potentially accurate, it is practically hard to use for measuring a whole projected area because of its slowness and manual alignment. To overcome these limitations, the high dynamic range (HDR) imaging method [Debevec and Malik 1997] is applied to the latest approach using a digital camera[Raij et al. 2003]. However, this approach has to mathematically derive the transfer function h_l from many images taken with different exposures, because of the limited dynamic range of common digital cameras.

Thus, we take advantage of raw digital images taken with a high-end digital camera and recently used for high-quality photo-imaging. To anticipate nonlinear responses in display devices, most digital cameras apply a nonlinear mapping to CCD outputs before they are written to a storage medium. However, in some high-end digital cameras, the original CCD outputs without the nonlinear mapping, which are the raw digital images, can be obtained in a special file format. By analyzing this format, we can access the original CCD outputs. The CCD outputs are proportional to the amount of light captured by the CCD. In other words, they are also proportional to the exposure. To obtain the transfer function h_l, we just normalize the outputs on the basis of their exposures. This approach excludes the complicated derivation of the transfer function h_l. Also, W_l requires this technique in order to easily measure the wide-range luminance variation between the bright center of projected images and the dark edge of those.

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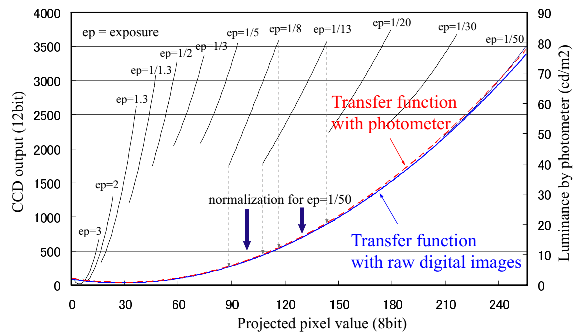
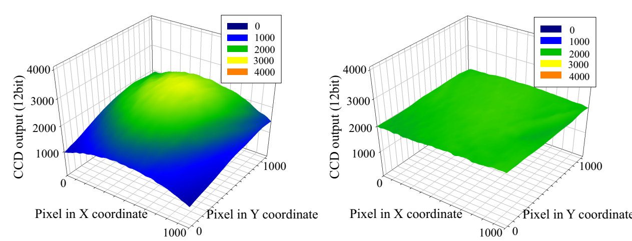


Figure 1: Transfer function obtained with raw digital images.

Figure 1 illustrates the transfer function obtained with our proposal technique using Nikon D2H and NEF file format (12bit). Raw digital images are obtained with a modified "dcdraw". Nowadays such a high-end digital camera comes down in price and becomes popular. Hence, this technique will be readily used for many kinds of projector-based display systems.

3 Results

We applied this proposal technique to practical luminance correction for a single projector. Figure 2 shows that the luminance irregularity in Figure 2(a) is effectively corrected as in Figure 2(b).



(a) Before the luminance correction (b) After the luminance correction

Figure 2: Luminance correction results.

References

DEBEVEC, P. E., AND MALIK, J. 1997. Recovering high dynamic range radiance maps from photographs. *SIGGRAPH97*, 369–378.

MAJUMDER, A., AND GOPI, M. 2005. Modeling color properties of tiled displays. *Computer Graphics Forum 24*, 149–163.

RAIJ, A., GILL, G., MAJUMDER, A., TOWLES, H., AND FUCHS, H. 2003. Pixelflex2: A comprehensive, automatic, casually-aligned multi-projector display. *PROCAMS-2003*.