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A QUANTITATIVE VISUAL EVALUATION METHOD FOR IN-VEHICLE OPTICAL DEVICES BY LIGHTING SIMULATION

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Abstract

In light of the acceleration of computer-aided model-based development, lighting simulation technologies that allow lighting environments to be repeatedly reproduced for a given time and space have become increasingly useful. Since products are often expected to be used in outdoor lighting environments, this study has been conducted to develop a technology for accurately reproducing such environments in the form of data with the aim of improving the accuracy of the lighting simulation. An omnidirectional camera, which is capable of taking photographs in all directions simultaneously, is used to acquire high dynamic range images called Light Probe that store omnidirectional light and colour information. We expanded the luminance dynamic range by compositing the images that were obtained by photographing the same scene while changing the photographable brightness range.

Keywords: Light Simulation, High Dynamic Range Image, Image Based Lighting.

1 Introduction

In image-based lighting (IBL), a high dynamic range (HDR) image is attached to the inner surface of an infinitely large sphere and the pixel values are expressed by using the colour and brightness of the light source. IBL is used to reproduce actual lighting environments in a lighting simulation (Figure 1). This paper describes a technology for expressing the light source information necessary for IBL in the form of data, which is currently under development.

2 Method

Images were photographed using a camera (THETA V; manufactured by Ricoh) capable of taking photographs in all directions simultaneously. The brightness range that can be acquired by electronic imaging equipment at one time (i.e., the luminance dynamic range) is limited, and luminance information is often not acquired. In this study, therefore, we composited multiple images to expand the luminance dynamic range in reference to the multiple-exposure method (Reinhard, 2010).

First, *N* copies of the original images $I_i(x, y, c)$ were photographed while the acquirable brightness range was changed by adjusting the camera's exposure time t_i (Figure 2 (a)). Here, i represents the image number ($1 \leq i \leq N$), x and y represent the pixel positions ($1 \leq x \leq 5\,376$, $1 \leq y \leq 2\,688$), and c represents a number corresponding to the colour channel ($1 \leq c \leq 3$).

Next, pixel value correction images $I_i{}'(x, y, c)$ were generated by correcting the pixel values of the original images according to the exposure time with the aid of Equation (1) so that the pixel values would be proportional to the actual brightness (Figure 2 (b)).

$$I_i{}'(x, y, c) = I_i \frac{(x, y, c)}{t_i} \cdots (1)$$

After that, an HDR image $H(x, y, c)$ was generated by averaging the pixel values corresponding to individual pixels on the pixel value correction images with the aid of Equation (2) (Figure 2 (c)).

$$H(x,y,c) = \frac{1}{N}\sum_{i=1}^{N} I_i'(x,y,c) \cdots (2)$$

Taking into consideration the linearity, halation, and black defects of camera output, pixels were used in the calculation only if the pixel values on all of the colour channels satisfy $I_{min} \leq I_i(x,y,c) \leq I_{max}$ at the individual corresponding pixels on the original images.

The HDR image that was generated was saved as data in the Radiance format with 32 bits for each colour channel, which can express approximately 4,2 billion tones ($0 \leq H(x,y,c) \leq 2^{32}$).

3 Result

Outdoor scenes were photographed as original images (N = 11) by adjusting the exposure time t_i from 1/2sec. down to 1/1 600sec. Figure 3 (a) shows original image I_9 (t_9=1/320sec.), while Figure 3 (b) shows the generated HDR image. Figure 4 shows the relative luminance (IEC, 1999) on the cross section indicated by a dotted line in each of the images shown in Figure 3. In original image I_9 (t_9=1/320sec.), the pixel values are saturated in the sky region (indicated by a broken line in Figure 4). In the HDR image, however, changes in the luminance are expressed as data within the entire region extending from the ground to the sky (indicated by a solid line in Figure 4).

4 Conclusion

In reference to the multiple-exposure method, we developed a technology for reproducing outdoor lighting environments in the form of data that can be used in lighting simulations. We will calibrate pixel values of HDR image in absolute luminance so that lighting simulations can predict luminance measurement results that are equivalent to the actual measurement results.

References

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IEC 61966-2-1:1999. *Multimedia systems and equipment - Colour measurement and management - Part 2-1: Colour management - Default RGB colour space – sRGB.* Geneva; IEC.

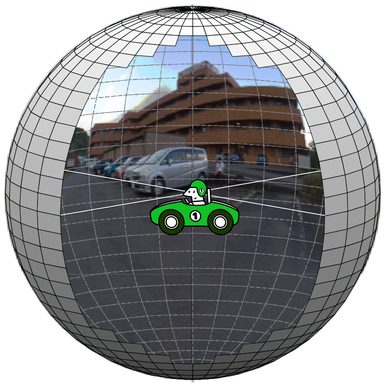

Figure 1 – Concept of Image-based Lighting

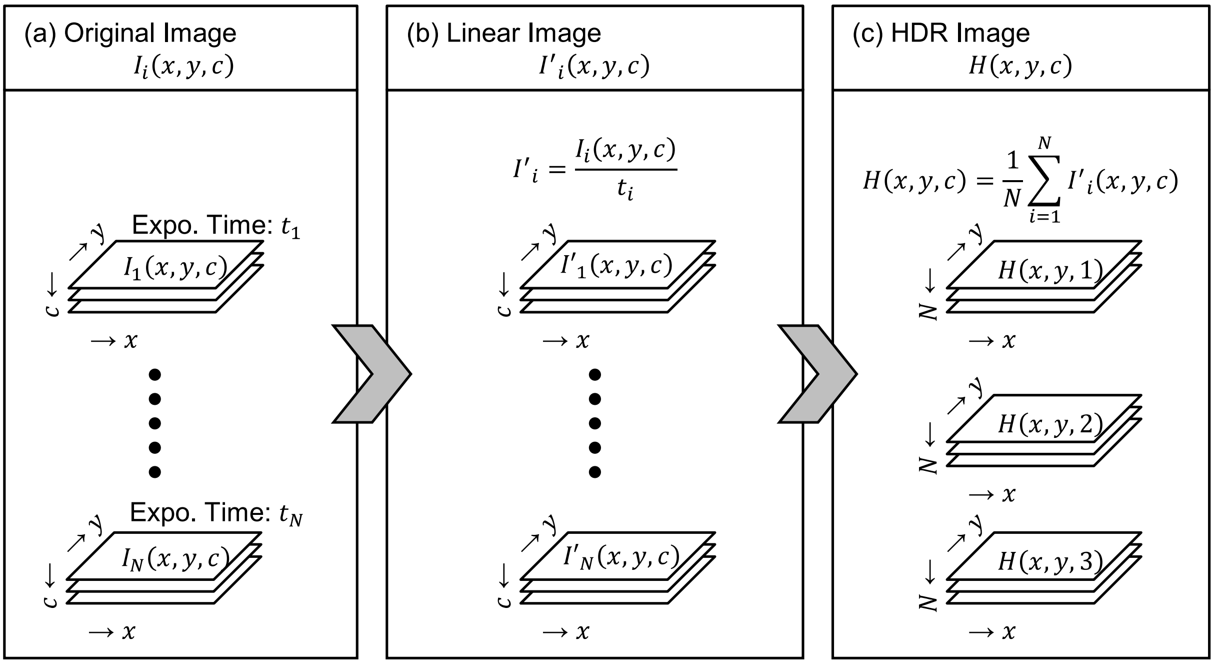

Figure 2 – Procedures for Generating HDR Image

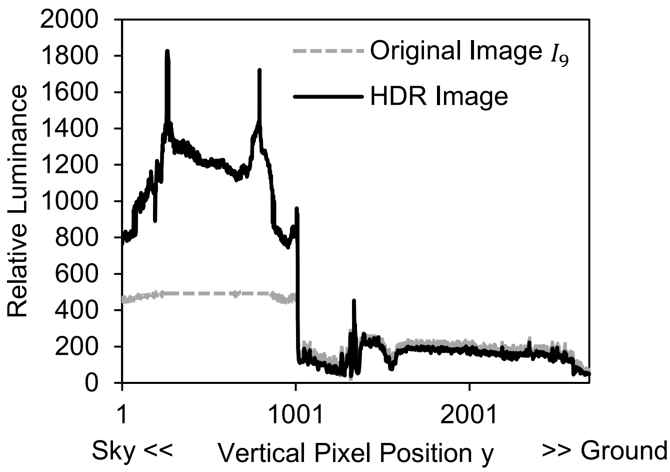

Figure 3 – Relative Luminance Distribution Comparing the Original Image and the HDR Image