International Commission on Illumination
Commission Internationale de l'Eclairage
Internationale Beleuchtungskommission

PO154

DEVELOPMENT OF GENERIC COLORIMETRY SYSTEM FOR EVALUATION OF LIGHTING ENVIRONMENT

Hideki Yamaguchi et al.

DOI 10.25039/x46.2019.PO154

from

CIE x046:2019

Proceedings
of the
29th CIE SESSION
Washington D.C., USA, June 14 – 22, 2019

(DOI 10.25039/x46.2019)

The paper has been presented at the 29th CIE Session, Washington D.C., USA, June 14-22, 2019. It has not been peer-reviewed by CIE.

CIE Central Bureau
Babenbergerstrasse 9
A-1010 Vienna
Austria
Tel.: +43 1 714 3187
e-mail: ciecb@cie.co.at
www.cie.co.at

DEVELOPMENT OF GENERIC COLORIMETRY SYSTEM FOR EVALUATION OF LIGHTING ENVIRONMENT

Yamaguchi, H. [1], Takasugi, K. [2], Sakurai, M. [3], Kato, M. [4], Hara, N. [5]
[1] National Institute for Land and Infrastructure Management, Tsukuba, JAPAN,
[2] Kanazawa University, Kanazawa, JAPAN, [3] Shizuoka Institute of Science and Technology, Fukuroi, JAPAN, [4] Nihon University, Narashino, JAPAN, [5] Kansai University, Suita, JAPAN

yamaguchi-h92ta@mlit.go.jp

DOI 10.25039/x46.2019.PO154

Abstract

To develop the lighting design method based on the comfort of the visual environment, it is necessary to have a luminance and chromaticity distribution measurement tool which is versatile and easy to construct the system. Therefore, it was developed a measurement system for luminance and chromaticity distribution of field of view using arbitrary digital camera. In this paper, it was examined the algorithm to convert digital camera images into the CIE XYZ tristimulus values and confirmed the photometric accuracy of their converted values.

Keywords: Colorimetry, XYZ tristimulus values, Luminance distribution, Digital camera

1 Introduction

It is important to further develop and disseminate energy conservation design methods in recent years. Further improvement of energy conservation performance of buildings is required. On the other hand, comfort of the visual environment must also be adequately guaranteed. The evaluation method of the comfort of the visual environment, such as the spatial brightness and glare, have been studied, and estimation methods of visual comfort are being developed (AYA et al., 2015), (NAKAMURA et al., 2015). To evaluate the spatial brightness or glare for the real environment, the luminance distribution of the field of view is required, and image photometry method is usually used to obtain the luminance distribution. But it takes a lot of time to build up the measuring system.

To build up the system, knowledge of image processing and hardware control is necessary. Especially, to acquire the skill of hardware control takes a lot of time for researchers or designers who want to evaluate light environment. The important issue for researchers or designers is to reveal the relationship between the luminance distribution and the light environment assessment. It is a waste of time for individual researchers and designers to independently develop measurement systems. To develop the lighting design method based on the comfort of the visual environment, it is necessary to have a luminance and chromaticity distribution measurement tool which is versatile and easy to construct the system.

Therefore, it was developed a measurement system for luminance and chromaticity distribution of field of view using arbitrary digital camera. We named this measurement system L-CEPT (Luminance and Colour Environment Photometric Tool). In this paper, it was examined the algorism to convert digital camera image into the CIEXYZ tristimulus values and confirmed the photometric accuracy.

2 Methodology

2.1 System Configuration

Figure 1 shows an outline of the measurement system configuration. This system consists of any commercially available digital single lens reflex camera (Picture Transfer Protocol supported) and a Linux PC (OS: Raspbian). This system has three functions: image shooting, image development, and image conversion to colorimetric values. The image shooting function is to control camera device with the external software (gPhoto2: http://www.gphoto.org) so that it can shoot with any camera. Thus, it is possible to us to construct a system with various

cameras. The image development function is also linked with external software (dcraw: https://cybercom.net/~dcoffine/dcraw/) so that raw data of an arbitrary camera can be converted into an uncompressed RGB value image (tiff format). The image conversion from the uncompressed RGB values image to the luminance and chromaticity values image is the same as the method used for general image photometry in shown next section. By creating an interface that combines these functions into one, it was constructed a measurement system compatible with arbitrary digital cameras.

Figure 1 – Outline of the measurement system.

2.2 System Algorithm

2.2.1 Basic Formula

Regarding to the image conversion from the uncompressed RGB values image to the luminance and chromaticity values image, the XYZ tristimulus values of each pixels are converted by that the RGB values multiply 3x3 matrix as shown in equitation (1).

$$\begin{pmatrix} X \\ Y \\ Z \end{pmatrix} = \frac{1}{Et} \begin{pmatrix} a_0 & a_1 & a_2 \\ a_3 & a_4 & a_5 \\ a_6 & a_7 & a_8 \end{pmatrix} \begin{pmatrix} R \\ G \\ B \end{pmatrix} \tag{1}$$

where

X, Y, Z	are the CIE 1931 tristimulus values;
R, G, B	are the RGB signals captured by camera;
a_i	is the transform coefficient;
Et	is the duration of exposure.

2.2.2 System Flow

Figure 2 illustrates the measurement system flow. First, the system loads a camera information file, which includes pixel format, list of shutter speed, list of ISO sensitivity and raw image extension that can be set in the camera. The system also loads the conversion matrix as denoted a_i in equation (1).

Eleven raw images are captured with different exposure levels for the scene to obtain a luminance and chromaticity distribution. The eleven raw images are developed with a gamma curve set as one and converted to RGB images. Therefore, the RGB values of each pixels are linearly varied with photometric values.

For all pixels of all images, RGB values are converted to XYZ values using equation (1), and these are combined to generate a csv file of luminance and chromaticity distribution.

2.2.3 Calibration

The most important point when set up this system is calibration to find the conversion matrix. The conversion matrix is obtained by acquiring an image of a color chart, such as Macbeth color checker, whose XYZ value is known and comparing it with the RGB values. Figure 3 shows the top view of calibration chamber. In this chamber, the Macbeth colour chart is

illuminated uniformly by lamps equipped on both sides. For camera calibration, three-wavelength fluorescent lamps (CCT: 5000K, Ra: 84) were used to illuminate the Macbeth

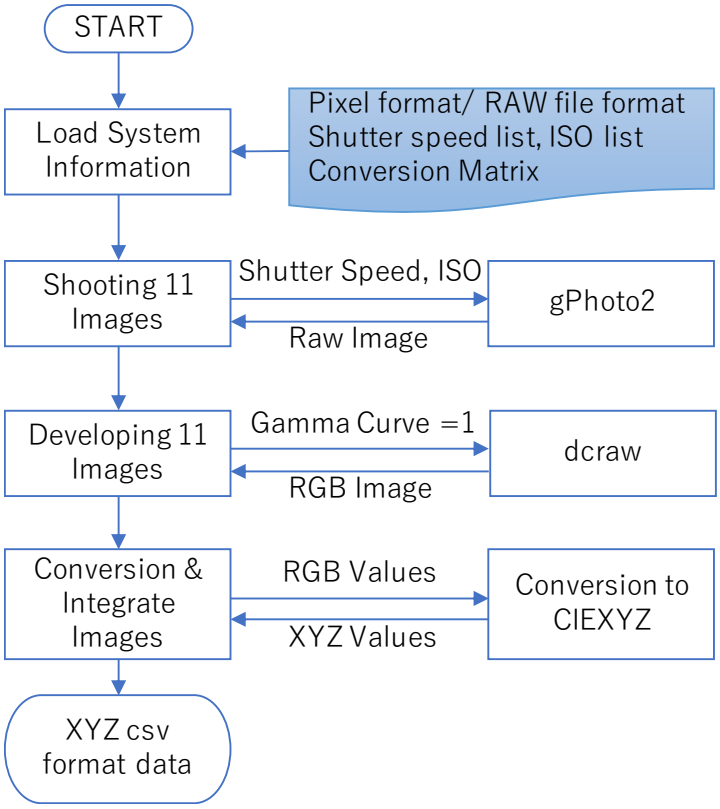

Figure 2 – System flow

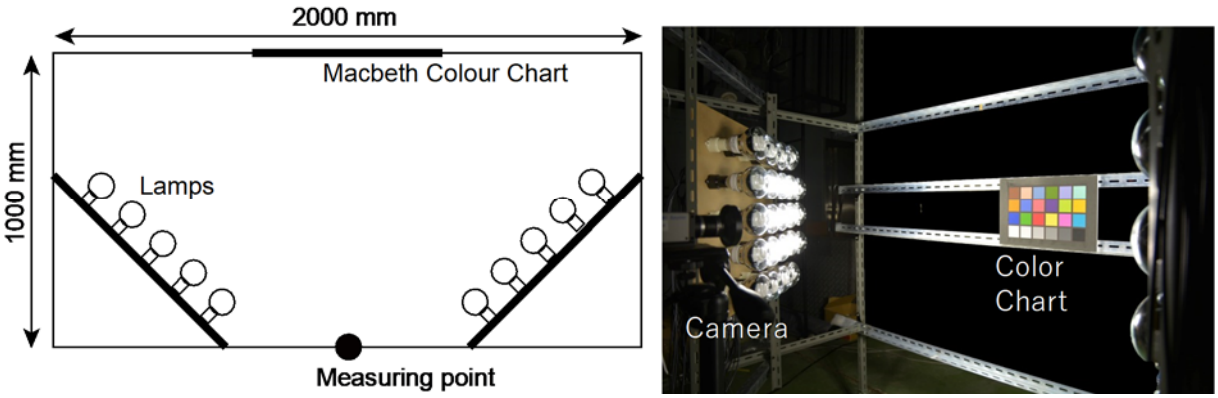

Figure 3 – Top view of calibration chamber

Table 1 – Tristimulus values of Macbeth colour chart

	dark skin	light skin	blue sky	foliage	blue flower	bluish grenn	orange	purplish blue	moderat e red	purple	yellow green	orange yellow
X	338.1	1085.7	487.3	308.3	653.6	868.5	1062.7	342.1	854.9	220.1	941.5	1330.6
Y	309.5	1010.0	525.5	404.0	636.5	1175.0	879.0	321.5	586.0	178.5	1225.0	1235.0
Z	146.0	514.1	685.1	134.7	845.8	875.8	146.2	710.3	282.7	289.2	226.1	166.7
	blue	green	red	yellow	magenta	cyan	N9.5	N8	N6.5	N5	N3.5	N2
X	202.3	451.7	609.2	1550.2	814.4	401.0	2334.6	1543.5	930.0	517.4	248.0	90.8
Y	167.0	696.5	365.5	1640.0	552.5	520.5	2475.0	1640.0	986.0	551.5	264.5	96.0
Z	548.3	208.2	113.1	198.2	609.8	785.0	1720.7	1201.5	748.8	413.6	206.3	75.5

colour chart. Luminance of each colour chips was varied by increasing/decreasing number of lamps. Three levels of illumination intensity were used for calibration. The CIEXYZ values of each colour chips measured by colorimeter (CS-100A, KONICA MINOLTA) are shown in table 1. These values were measured when the illumination intensity was set at max level. For these colour chips, we took eleven images which were set up different exposure times. The transform coefficients a_i are derived by using the multiple regression analysis from XYZ obtained by measured values and captured pixel RGB values.

3 System Accuracy

In this paper, it was examined the system accuracy for two models of cameras, one is Nikon D3100, and the other is Canon 5D Mark III.

Figure 4 shows the comparison between value measured by the system and value measured by a CS-100A for Macbeth colour chips used for calibration. The upper left is the comparison of luminance values measured by the Nikon D3100, and the upper right is the comparison result measured by the Canon 5D Mark III. The horizontal axis shows the luminance measured by the system, and the vertical axis is the luminance measured by CS-100A. Measurement error may be up to about 10% error, but we believe that it is a reasonable measurement result as a hardware-free system. The lower left graph shows the comparison of xy chromaticity in Nikon D3100, and the lower right in Canon 5D Mark III. The black circles are the output from the system, and the white circles are values measured by CS-100A. It was shown that although the error was slightly seen in the area where the saturation was high, it could be measured approximately.

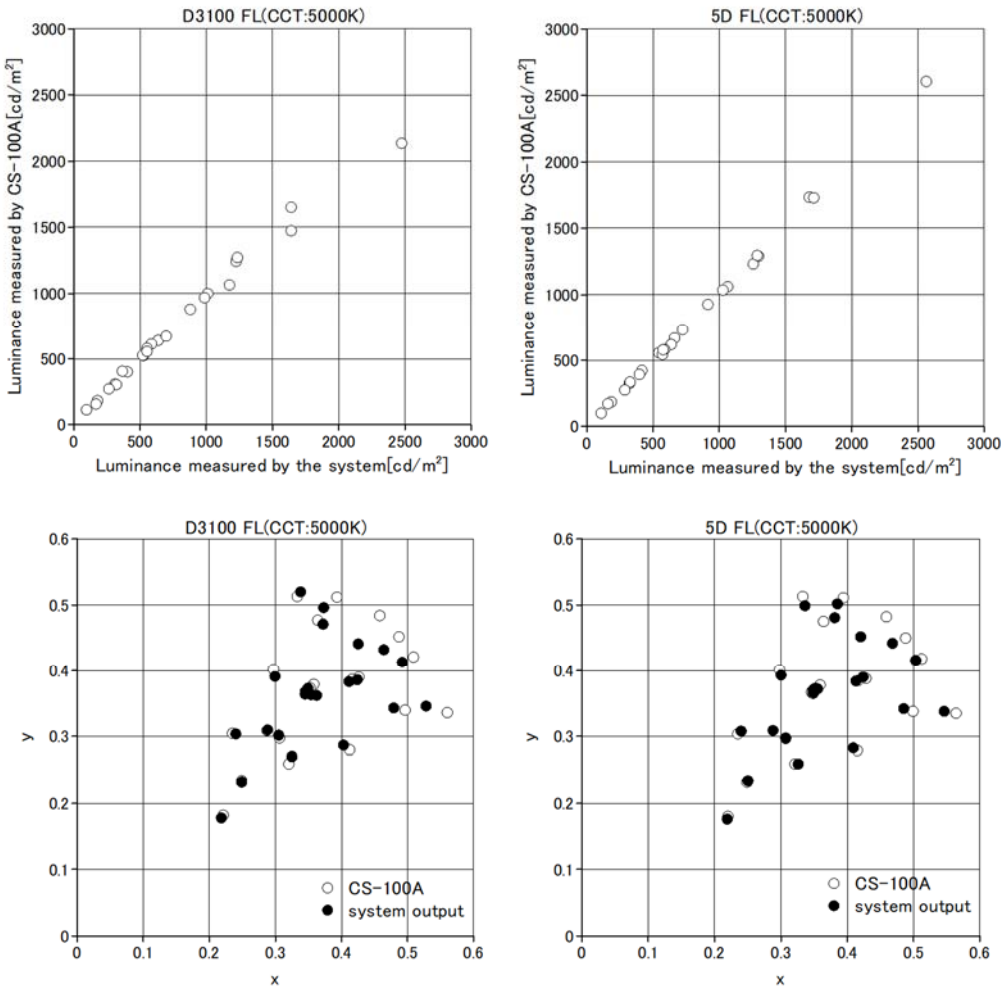

Figure 4 – Comparison of luminance and colour coordinates (CCT:5000K)

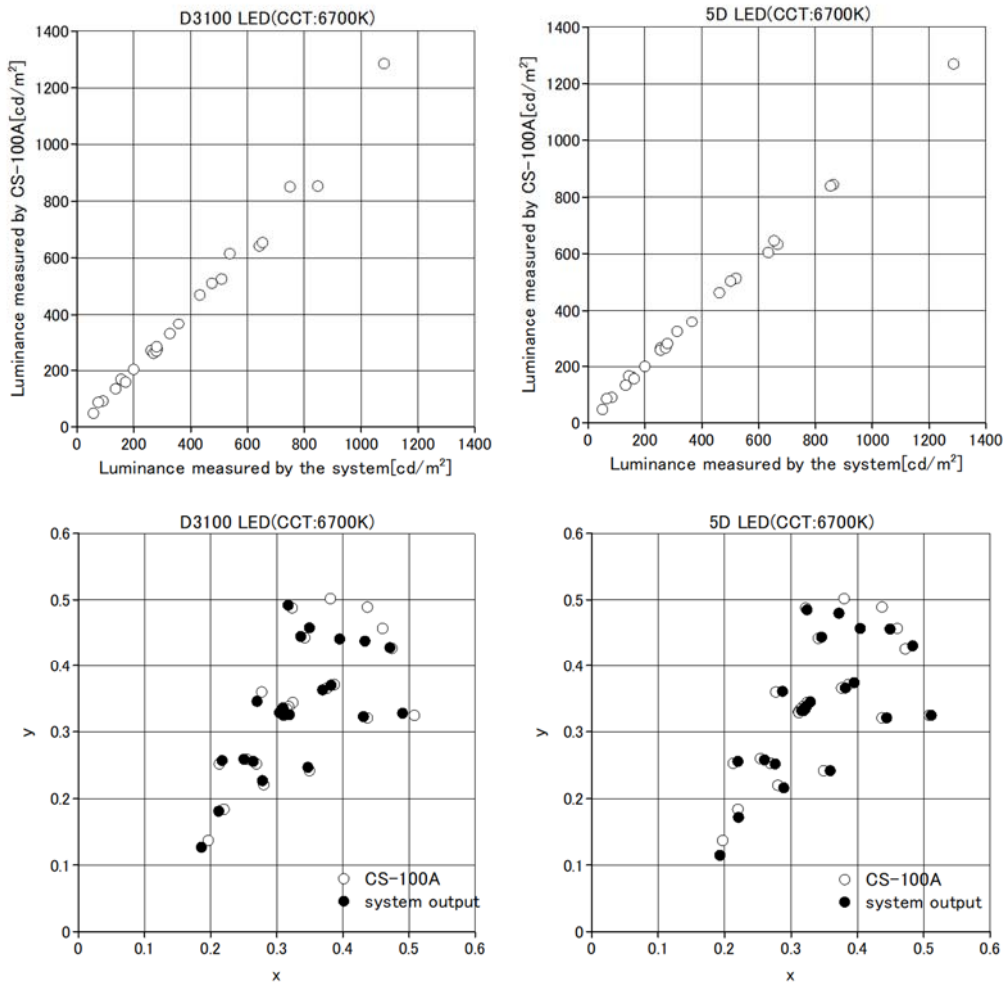

Figure 5 – Comparison of luminance and colour coordinates (CCT:6700K)

Figure 5 shows the result of confirmation of the measurement accuracy when the illumination light to the Macbeth colour chip is changed to the LED (CCT:6700K). Although colour of illumination is different from the colour when the system calibration was done, it was confirmed that an accuracy of the measurement system is almost same as that under the colour of illumination of calibration.

4 Conclusion

As described above, it becomes possible to construct a photometric system compatible with arbitrary cameras easily, and it is expected that progress of research and development on the comfort evaluation of the visual environment.

References

AYA, K., YOSHIZAWA, N., YAMAGUCHI, H., HARA, N., KATO, M. and MIKI, Y. 2015. The Relationship Between the Brightness of Overall Space and the Brightness in the Specific Visual Field in the Non-Uniform Illuminated Space. *Proceedings of 28th CIE Session,* 1466-1470.

NAKAMURA, Y. and OKADA, S. 2015. Brightness-Matching Experiment to Improve Luminance-Brightness Image Conversion System. *Proceedings of 28th CIE Session,* 1460-1465.