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The impact of distance on the accuracy of luminance measurement

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Abstract

Many researchers want to reduce the severe luminance difference caused by artificial lights or natural lighting and when luminance is highly uniform. This paper focused on the correlation between measured luminance and the distance of measurement from the light source. For this task, two types of luminance measuring methods were adopted. Namely, High Dynamic Range (HDR) image processing and CS-100 instrument for measuring surface luminance and point luminance respectively. The results indicate that there was a 3% decrease in measured luminance as the distance from the light source was increased by 1m.

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Keywords: luminance; brightness; measuremnt of luminance, HDR

1. Introduction

The night landscape of a city consists of roads, infrastructure facilities and buildings lighting. Especially, buildings lighting which reveals various formative characteristics of buildings at night and makes them significant in creating a night time image somehow different from that of daytime. Harmonious distribution of luminosity is a critical consideration in lighting design of buildings, and such assessment is definitely needed. In addition, considering the issue of light pollution caused by excessive lighting these days, a quantitative evaluation of the lighting design seems essential. Luminance measurement can be done through surface luminance measurement using HDR image processing and point luminance measurement using CS-100. The quantity of light received at the device

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is converted into luminance. Normally, Luminance can be classified into luminance that is directly from the light source and luminance that is reflected from an object [1].

Thus, the measured luminance value differs according to the distance from a light source and light source's orientation, and such should be considered before proposing the criteria for light pollution. Furthermore, when measuring an outdoor light source, according to the luminance measurement method, any light source in the surrounding may have an influence on the luminance of targeted light source. Therefore, this study examines luminance changes according to the alteration of distance and angle of the measurement surface, and the relation between the measured light source and its surroundings.

2. Luminance measurement theories

The existing landscape lighting evaluation method which takes into account of improving the aesthetic aspect of urban night landscape, securing visual safety and preventing light pollution is focused on analyzing the photometric quantity by limiting the measurement area to a single point. This makes it difficult to understand and evaluate the surface luminance changes according to the distance. Many researchers conducted a study to examine correlations between the light source luminance, light source area, louver type and background luminance using an evaluation equation in which discomfort glare caused by an artificial light source at indoor environments, excluding the daylight, is applied. The impact on the discomfort glares according to the changes of the light source luminance, light source area and luminance ratio was quantitatively analyzed and the correlations were drawn. Also, they proposed that the existing evaluation equation which was considering four factors (luminance, location, size and background of light source) has a problem in calculating the luminance and discomfort glare. The studies described previously are conducted assuming that the measurement instruments are reliable, yet they do not include the issue of distance, angle and neighboring light sources indicated in this study.

In this section, the basic concept of luminance is defined and the methodologies of measuring luminance are specified

2.1 Definition of luminance

In general, luminance refers to the intensity of light entering human eyes. The term luminance used in the display industries represents the luminescence intensity of display. In the light environment of buildings, it is generally defined as the brightness entering human eyes as the light emitted from lighting fixtures is reflected from the surface of walls, ceilings, floors or objects. When the difference of luminance between the indoor surfaces is severe, it will break the indoor brightness balance, and when there are several surfaces with extremely high luminance difference within the field of vision, it will hinder visual performance and generate discomfort. For a pleasant visual environment for the occupants inside a building, designers reduce the severe luminance difference caused by artificial lights or natural lighting and when luminance is highly uniform, visual fatigue is avoided by preventing the indoor atmosphere from becoming monotonous. The general equation of luminance proposed by CIE is as shown in the following Formula. Candela per square meter (cd/m2) is applied as the unit.

$$L = \frac{d^2\Phi}{dA\,d\Omega\cos\theta} \tag{1}$$

- L is the luminance (cd/m2)
- Φ is the luminous flux or luminous power (lm),
- θ is the angle between the surface normal and the specified direction,
- A is the area of the surface (m2), and
- Ω is the solid angle (sr).

The above formula gives the luminance (L) directly from the light source. However, in building lighting, there is also luminance entering the human eyes after several reflections from objects surfaces and these two types of luminance have great impact on visual work capacity.

$$L_v = \frac{d^2 \Phi_v}{dA\, d\Omega \cos\theta} \tag{2}$$

L_v is the 'visual' luminance (cd/m2)
Φ_v is the 'visual' luminous flux or luminous power (lm),
θ is the angle between the surface normal and the specified direction,
A is the area of the surface (m2), and
Ω is the solid angle (sr).

Unlike Formula (1), Formula (2) represents the luminance in the view of a person. Although it is calculated with the same quantity as that of Formula (1), the term 'Visual' is defined along with the abbreviation of luminance, L. The same formula is applied to the point and surface luminance measurement methods. Two representative methods of measuring the brightness of objects do not estimate the absolute luminance values of illuminating surfaces, rather they accept that luminance values can change according to the light velocity accepted by the meters [2].

2.2 Point luminance measurement method

As mentioned in the introduction, currently there are 2 methods used for luminance measurement. The first one is the use of CS and LS equipment when measuring the point luminance and the other one is the use of HDR image processing for surface luminance measurement. The CS and LS equipment that can measure the point luminance have difficulty in measuring the accurate luminance values when measuring the surface of light sources. For instance, in the case of LS-100, when the measurement range exceeds 1°, the luminance value is measured differently and the luminance error of the measured surface can be reduced when the diameter of the measured surface is at least 14.4mm and the minimum distance is 40 inches (1014mm). In other words, a difference may be generated according to the diameter and distance of the light source measured. Figure 1 is the picture of CS-100 device used for point luminance measurement and the actual measurement.

Fig. 1. CS-100 used for point luminance measurement

2.3 Surface luminance measurement method

In the cases of CS-100 and LS-100 optical instruments, SLR (Single-Lens-Reflex) optical meter is used for measurement, which allows accurate measurement as well as high-brightness measurement. However, in case of HDR, it uses the image sensor of CCD, not the photoelectric element measured using a digital camera, in order to obtain luminance information as the collection of RGB digital information per pixel. The luminance contrast that a single photo can have using a digital picture is 1:10000, and it cannot simultaneously meet the luminance conditions that the human eyes can detect. Thus, HDR (High Dynamic Range) technology is used for composition of several pictures so that the luminance contrast is 1:100000, which is actually detectable by human [8]. Figure 2 shows the correlation of exposure value and luminance that can be measured according to the camera exposure and shutter speed [3, 4, 5, 6, 7].

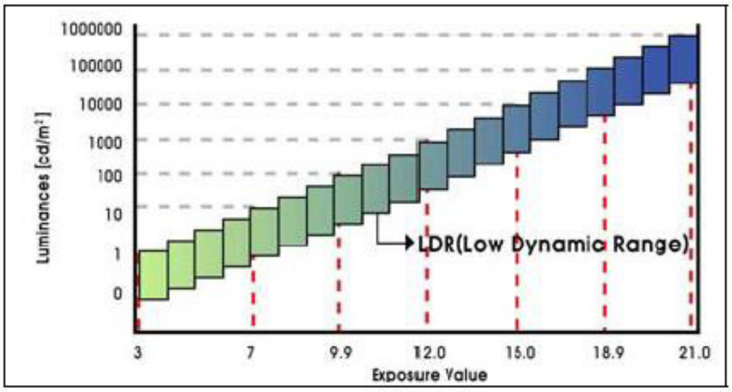


Fig. 2. Correlation of exposure value and luminance

HDR image processing can be applied to measure the uneven surfaces, but the luminance values calculated according to the color temperature and size of light source and the distribution of light distribution curve may vary. Such characteristic is adopted for use when operated under the applicable 'Act on Prevention of Light Pollution caused by Artificial Lighting. Figure 3 demonstrates the case of luminance measurement using LMK inside the sky simulator at Kyung Hee University. A sky simulator is a closed space made for the purpose of imitating the appearance of the natural and empty sky. Table 1 shows the LMK image setting range for luminance estimation.

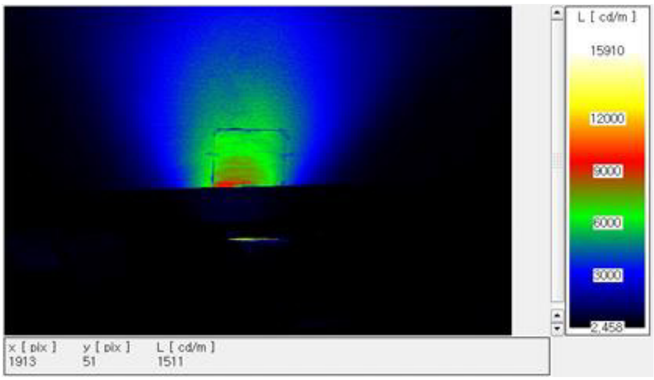


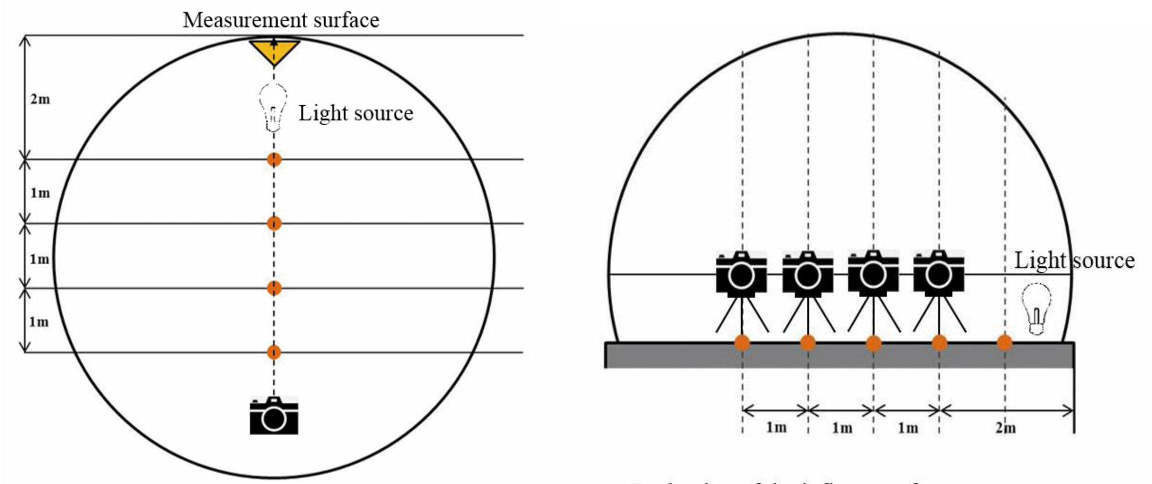
Fig. 3. HDR Image for surface luminance measurement

Table 1. LMK image setting range for luminance estimation

Aperture	Exposure time
3.8	1/2
3.8	1/15
3.8	1/125
3.8	1/1000

3. Research design

This study aims to examine the luminance changes according to the measurement distances. The study was performed in the sky simulator at Kyung Hee University to reduce the light scattering effects. During this experiment, the light source illuminates on a particular surface inside the sky simulator and the surface of primary reflection became the measurement surface for evaluation. The initial measurement distance is 2m from the measurement surface and other values were measured at 1m interval. This experiment was made for both the point and surface luminance as shown on the figure 4.



Evaluation of the influence of measurement distance on luminance (full view).

Evaluation of the influence of measurement distance on luminance (cross-section view).

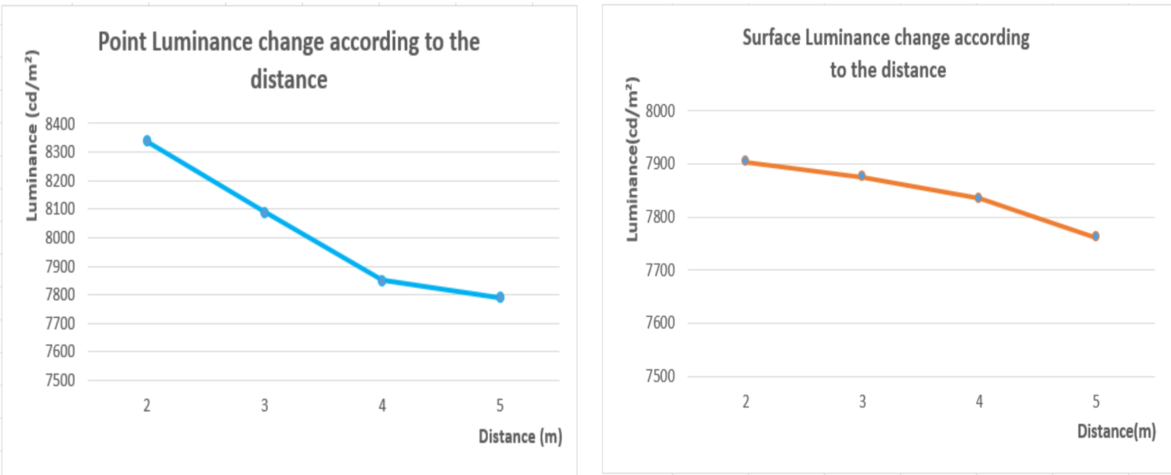
Fig. 4. Experiment for measurement distance influence on luminance.

4. Results

The results were analyzed for both surface and point luminance measurements. The changed value and ratio according to distance were calculated based on the luminance value at 2m from the measurement surface (table2). Below are the graphs showing separately how the point luminance and surface change according to the distance. Based on the reference point, it is shown that the luminance value decreases for about 3% as the measurement distance gets farther by 1m, and the maximum difference value was 550 cd/m2 obtained from point luminance measurement.

Table 2. Luminance changes according to the change of distance

Device	Measurement distance(m)	Measured luminance(cd/m^2)	Changed value based on initial point(cd/m^2)	Changed ratio based on initial point (%)
CS-100	2	8340	-	-
	3	8090	250	3
	4	7850	490	6
	5	7790	550	7
LMK	2	7904	-	-
	3	7875	29	0.4
	4	7835	69	1
	5	7761	143	2



(a) Point luminance (b) surface luminance

Fig.5. distance and luminance values

5. Conclusion

This study was intended to examine the luminance changes according to the altered distance to analyze the relation between the targeted light source and the result using the instruments. From the experiment in relation to the luminance changes according to the distance, the results show that the difference in luminance value under the same conditions was around 5% when the point and surface luminance meters were used. With the point luminance, there was a difference of around 3% as the distance from the measured point increases by 1m. However, the impact of distance on surface luminance was smaller compared to the one of point luminance. This study's results imply that luminance values vary according to the measurement distance. It can impact the luminance values. Thus, it requires a reasonable standard on calculating the luminance under the "Act on Prevention of Light Pollution caused by Artificial Lighting".

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