Design methods for uniform illumination light device with LEDs: Boundary center matching and distribution approximation

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***Abstract*— This paper introduced new methods for designing uniform illumination light devices with LEDs array. These aim to determine the number of LEDs and optimize their locations. One is a simple expansion of center region sources to the boundary of the illumination area with contribution matching. The other suggests distribution approximation of optimal sources and precise locations are determined with estimation using a summation of Gaussian kernels. Both methods show improved uniformity for the given illumination area than filling light sources with Sparrow's criterion.**

I. Introduction

Uniform illumination light designs have been actively applied in various fields from street lamp arrangement problem to 3d printing (masked stereolithography). Since the development of LED devices, many optical devices have consisted of LEDs, because of their high efficiency for energy and small physical size. However, commercial LED modules usually show inhomogeneous luminous intensity for viewing angle and this makes it hard to construct uniform illumination on the target plane with an array of LEDs.

There has been a lot of research to overcome this limitation. One method is accomplishing a center flatness of the total illumination function. It uses Sparrow's criterion that vanishes 2nd derivation term at the center of the total illumination function [1]. Moreno et al expanded this method for the general number of sources in various forms of arrays(ESC) [2]. This calculation can provide very flat illumination near the center, however, it rapidly decreases near the boundary, because this method does not consider the permitted dimension of the given system.

This paper suggests two methods. One is an expanding center region to boundary with matching the contribution for center and boundary points(BCM). The other solves integral equation for total illumination and distribution of sources and approximates source distribution with finite dimension positive vector. Optimized locations of LEDs are determined with summation of Gaussian kernels using least square method.

II. Result and Discussion

For given optical system (s, W, H) = (1.11, 0.2(m), 0.05(m)), simulations of each method: ESC, BCM, and the distribution approximation(DA) are conducted, where s is a power of cosine in imperfect Lambertian and W and H are the width of illumination area and the distance between target area and LED plane, respectively.

Calculated illumination functions of each method are plotted in Fig. 1 with normalization. LED numbers are determined in calculation and CV(RMSE) values are calculated in Table. 1. Fig. 2 indicates that positive vector values from solution of integral equation and Gaussian kernel estimation in real physical dimension. BCM method loose its flatness near center, however overall uniformity was increased. Estimation of the distribution method can provide better uniform illumination for the entire region of the target area without loss of flatness at the center.

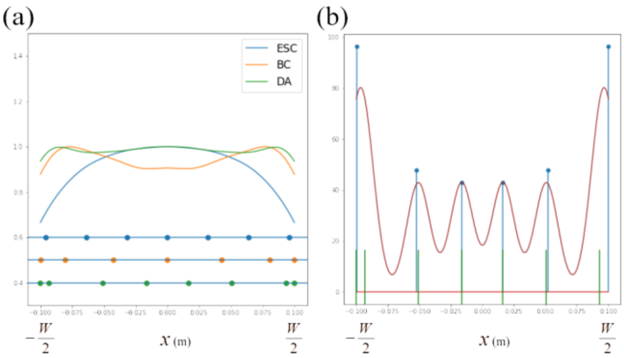

Fig.1 (a) Illumination graph of each 3 methods and corresponding source distributions (below lines and dots). (b) location estimation of DA method with Gaussian kernels.

Table. 1 Estimated uniformity and the number of LEDs.

Method	CV(RMSE)(%)	Number of LEDs
ESC	10.08	7
BCM	3.78	7
DA	1.18	8

References

[1] Richard Barakat, "Application of apodization to increase two-point resolution by the Sparrow criterion. I. Coherent Illumination", JOSA 52, Issue 3, 276-283 (1962).

[2] Ivan Moreno, Maximino Avendaño-Alejo, & Rumen I. Tzonchev, "Designing light-emitting diode arrays for uniform near-field irradiance", AO 45, Issue 10, 2265-2272 (2006).