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Transmittance Measurement Using Scanning LED

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ABSTRACT

In order to measure the transmittance for a large field of view (FOV), a system based on scanning LED is developed. The system mainly consists of tunable LEDs, a glass diffuser and a camera. The LED panel would display different colors in the CIE color space. An algorithm of converting the light wavelength to the RGB values is adopted. The images are captured using a monochrome camera. Depending on the number of colors displayed, the transmittance map for the entire spread of visible colors can be determined. Results are compared with those measured through a spectrometer. The spectral transmittance for the two methods exhibit good similarity. The system provides a means of measuring transmittance with no moving parts and can be extended to other hyperspectral imaging applications.

Keywords: Transmittance measurement, scanning LED, large FOV

1. INTRODUCTION

The basic concept behind optical spectral transmittance measurement is to use a broad spectrum (typically tungsten or xenon sources) blackbody light source and spectrometer which detects the intensity for the individual wavelengths[1-3]. If the intensity of the light source for a specific wavelength (λ) is I_0 (λ) , and the intensity of light when it traverses the object, which absorbs some of the light energy, is I(λ), then the transmission T of the object is defined as, $T(\lambda)=I(\lambda)/I_0(\lambda)$ with the assumption that the dark current intensity has been normalized. Basically, this method is mainly used for small area measurement with a small input beam diameter. For measuring the transmittance over a larger are, the object is usually scanned.

To get better results for diffuse samples, one favored method for measuring the light transmittance of a sample uses an integrating sphere[4-7] in an optical measuring system for detecting light accurately without causing errors in the measured value, even when the measured light is diffused by the sample. However, the integrating sphere is expensive thereby making it difficult and costly to distribute integrating spheres widely among optical measurements.

In this paper a transmittance measurement system based on a tunable light source is introduced. The basic concept of this system is to use light sources (typically LEDs) with different central wavelengths and wavelength spreads to cover the entire spectrum of the visible (and UV and IR bands). An array of such LEDs would provide a large Field of View (FOV) measurement. The recording CCD/CMOS cameras can be either monochrome or color. Analysis of the luminous transmittance for the different RGB values (or wavelengths) can then be calculated based on the transmittance over the entire FOV. Unless other hyperspectral imaging systems which utilizes a spectrometer to split the light and thus requires the so-called push broom method of acquisition, this system has no moving parts although we still record a stack of images for each RGB (or wavelength) value of the incident light.

2. TRANSMITTANCE MEASUREMENT SYSTEM

2.1 The system configuration

The system mainly consists of RGB LED matrix, glass diffuser, imaging lens and a camera. The configuration is illustrated in Figure1. In the experiment a 32x32 LED panel is used. The diffuser could provide uniform illumination.

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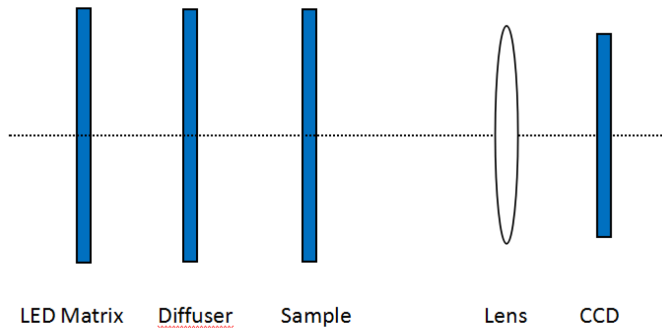

Figure 1. Setup of the Transmittance measurement system

2.2 Measurement procedure

There are two ways of measuring the hyperspectral transmittance. The first uses three (RGB) or more (ROYGBIV) LED central wavelengths, while the second uses combination of RGB values to record over 30 images at different 'colors'.

The recording flow for the first method is shown below.

a. Place the sample on the holder and focus the camera to record image of sample.

b. The three LED central wavelengths are sequentially lit up and the camera captures the three (or more) corresponding pictures, $I_{ms}(m = r, g, b)$. To depress random noises, multiple frames for a single wavelength can be recorded and averaged.

c. Remove the samples and repeat step b to obtain the three or more corresponding pictures $I_m(m = r, g, b)$.

Compute the spectral transmittance map of the sample as follows

The desired wavelengths $\lambda_m(m = 1,..., M)$ for which the transmittance has to be determined are chosen. Each wavelength is converted to a corresponding RGB value $(r_m, g_m, b_m)(m = 1,..., M)$ using a conversion algorithm[1]. The transmittance for each wavelength is then computed as follows.

$$t_m = \sum_{n=r_m,g_m,b_m} nI_{ms} \Big/ \sum_{n=r_m,g_m,b_m} nI_m \qquad (m = 1,..., M) \tag{1}$$

The second method records multiple RGB pictures. Multiple wavelengths $\lambda_m(m = 1,..., M)$ are chosen. Each wavelength is converted to RGB values $(r_m, g_m, b_m)(m = 1,..., M)$. The LEDs show the colors consequently and the pictures are captured. The steps are as follows.

Put on samples and adjust the lens to imaging the samples on the camera.

The LED matrix shows M colors $(r_m, g_m, b_m)(m = 1,..., M)$ and the camera captures three corresponding pictures $I_{ms}(m = 1,..., M)$. To reduce noise one could capture multiple pictures for the same RGB values and average them.

Remove samples and repeat step b to get the intensity $I_m(m = 1,..., M)$ without any sample.

Compute the spectral transmittance maps of sample as follows:

$$t_m = I_{ms}/I_m \qquad (m = 1,..., M) \tag{2}$$

2.3 Experiment results

A color sample is measured using the methods. Results are compared to those measured through spectrometers. The color sample is illustrated in Figure 2. It includes three different colors (red, green, blue).

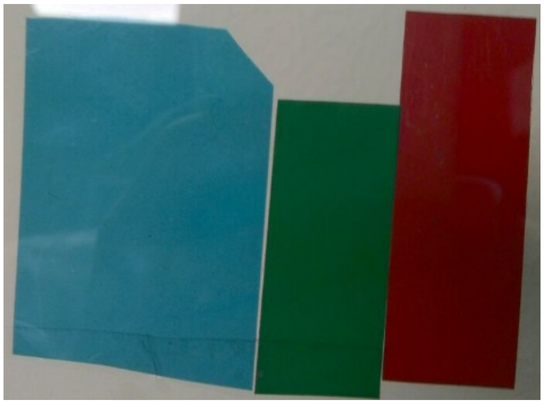

Figure 2. The color sample.

The spectral transmittance for the three parts are measured through spectrometer. The results are illustrated in Figure 3. The red, green and blue parts have a transmittance peak respectively at about 650nm, 520nm and 490nm.

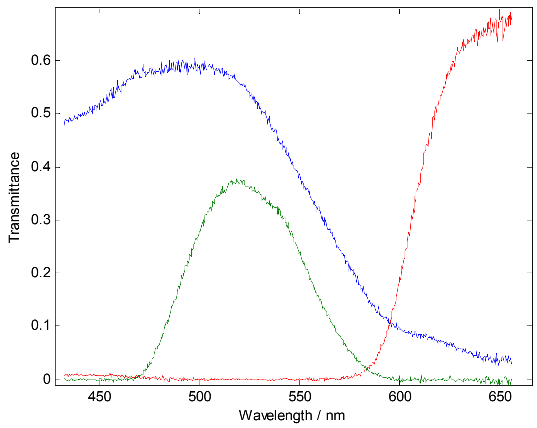

Figure 3. The spectral transmittance for three parts of the color sample

The transmittance maps measured for three colors (red, green, blue) are illustrated in Figure 4.

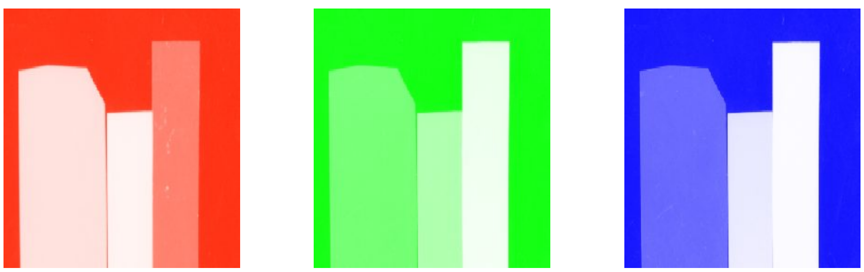

Figure 4. The transmittance maps measured for red, green and blue.

The hyperspectral transmittance of three pixels respectively from the three parts are illustrated in Figure 5. The two methods get very similar results. Also the curves exhibit certain similarity to Figure 3. As the conversion algorithm[8] of wavelengths and RGB values is a piecewise function, the curves have typical inflection points.

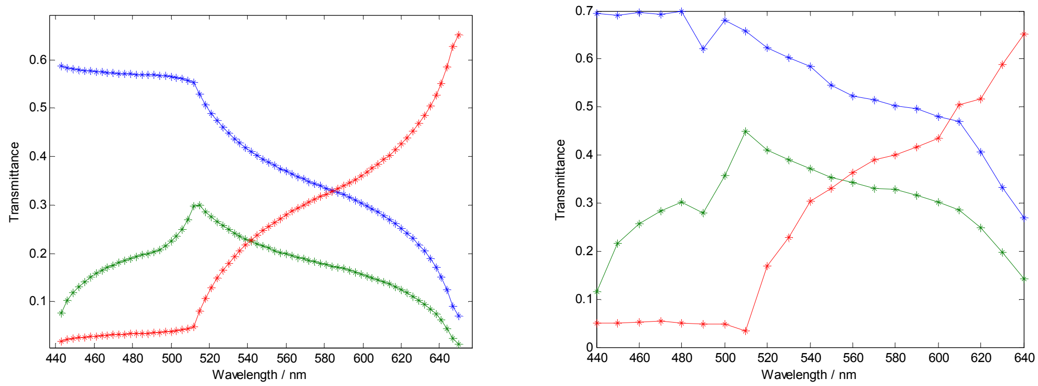

Figure 5. The hyperspectral transmittance of three pixels respectively from the three parts. (left) For method 1. (right) For method 2.

3. CONCLUSIONS

This paper introduces a transmittance measurement system based on scanning LED. The system measures hyperspectral transmittance for large FOV through tunable LEDs with a range of central wavelengths enabling any value in the CIE color space and beyond to be displayed. Depending on the number of colors displayed, the transmittance map for the entire spread of visible colors can be determined. Results are compared with those measured through a spectrometer. The spectral transmittance for the two methods exhibit good similarity.

REFERENCES

[1] F. Manoochehri, E.lkonen, “High-accuracy spectrometer for measurement of regular spectral transmittance”, Applied Optics, Vol. 34(19), 3686-3692 (1995)

[2] David A.C. Compton, John Drab and Howard S.Barr, “Accurate infrared transmittance measurements on optical filters using an FT-IR spectrometer”, Applied Optics, Vol.29 (19), 2908-2912 (1990)

[3] Z. M. Zhang, L. M. Hanssen and R.U. Datla, “High-optical-density out of band spectral transmittance measurements of bandpass filters”, Optics Letters, Vol.20(9), 1077-1079 (1995)

[4] Matti Mottus, Aarne Hovi and Miina Rautiainen, “Theoretical algorithm and application of a double integrating sphere system for measuring leaf transmittance and reflectance spectra”, Applied Optics, Vol. 56 (3), 563-571 (2017)

[5] Annica M.Nilsson, Andrea Jonsson, Jacob C.Jonsson and Arne Roos, “Method for more accurate transmittance measurements of low angle scattering samples using an integrating sphere with an entry port beam diffuser”, Applied Optics, Vol. 50(7), 999-1006 (2011)

[6] Leonard Hanssen, “Integrating-sphere system and method for absolute measurement of transmittance, reflectance, and absorptance of specular samples”, Applied Optics, Vol.40(19), 3196-3204 (2001)

[7] Jeffrey Kessel, “Transmittance measurements in the integrating sphere”, Applied Optics, Vol. 25(16), 2752-2756 (1986)

[8] Dragos Mihai, Eugen strajescu. From wavelength to RGB filter. U.P.B.Sci.Bull., Series D, Vol69, No. 2, 77~84 (2007)