PWSOI-15

USING ADAPTIVE MATRIX TRANSFORMATION FOR DECREASING COLOUR MEASURING SYSTEMATIC ERROR IN IMAGE TAKING TRISTIMULUS COLORIMETERS

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In image taking colorimetry the tristimulus technique is still the practical viable method if the measuring time should be kept in limits. Due to the fact that the number of coloured glasses that are available to adjust the detector responsivity to the CIE colour matching functions (CMF) is limited and the number of the filters used in a channel can not be increased without limits to decrease the adjustment error, as this would decrease the sensitivity of the colorimeter, the systematic errors of such instruments is substantial.

Some considerable time ago one of the present authors described a tristimulus colorimeter where the output signals of the four channels (X_{short}, X_{long}, Y and Z) were multiplexed (in those days with an analogue multiplexing circuit) to increase the measuring accuracy (as it was called in those days) of the colorimeter[3]. The technique was used advantageously in building colorimeters for cathode ray tube (CRT) colorimetry[4], as in this case the matrix enables to set the readings of the instrument to their correct values for all three basic stimuli of the CRT.

As a further new demand to above considerations came the request to be able to measure the colour not only in one spot, but in the entire scene, thus image taking colorimeters had to be developed. Although there are some (mainly custom built) image taking spectro-colorimeters, the majority of such instruments are based on the tristimulus principle, especially because the spectral instruments are extremely slow and suffer – for the time being – from bandwidth problems as well. In an earlier paper the theoretical possibility of decreasing the measurement uncertainty of tristimulus (image taking) colorimeters by using digital matrixing of the signals[5] was discussed. This technique increases the measurement time only by the measurement using the extra channel.

In recent years the request of measuring the chromaticity of light emitting diodes (LEDs) became of paramount importance. For these narrow band sources even small deviations of the spectral responsivity from the CMFs produces unacceptably large measurement errors. As was shown in an earlier paper[6] if we use 5th and 6th channels and use matrix

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[3] Schanda J, Lux G. On the electronic correction of errors in a tristimulus colorimeter. *AIC Colour 73*, York, Hilger, London, 466-469, 1973.

[4] Eppeldauer G, Lux G, Schanda J. A hibák elektronikus javítása a fényforrások tristimulusos szinmérésében (Electronic correction of tristimulus colour measurement of light sources) *Mérés és Aut.*, 22/10, 383-386, 1974.

[5] Schanda J, Sik-Lányi C, Kosztyán Zs, Csuti P, Schanda Gy Colour measurement of LEDs, problems and corrections. *AIC Midterm Meeting*, Hangchou, China.

[6] Zs. Kosztyán, S. Sturm, D. Müller, J. Schanda: Decreasing Colour Measuring Systematic Error in Image Taking Tristimulus Colorimeters, CIE Expert Symposium on Advances in Photometry and Colorimetry, 7-8 July 2008, Turin (Torino), Italy, pp. 21-25.

transformation, the measurement error can be decreased drastically. Optimum performance can be achieved if the matrix is specially designed for the given colour of the LEDs to be measured.

Colour LEDs can be estimated by very simple functions: Gauss function, triangle function, beta power distribution as shown in Figure 1. An optimal matrix transformation can be determined for the estimated spectral power distribution and can be tested to the real colour LED.

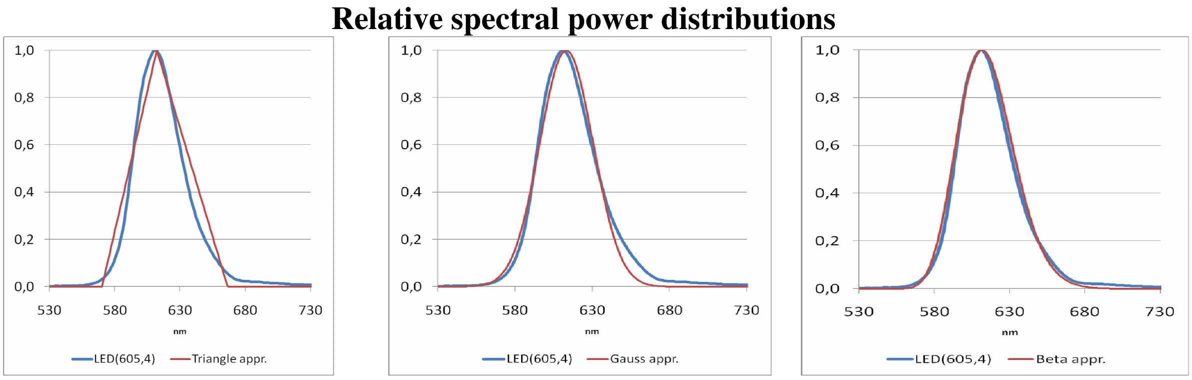

Figure 1. Relative spectral power distribution of LED(605,4) and its approximations using triangle, Gauss and beta distributions.

In this process first of all the approximate chromaticity coordinates of the LEDs must be determined with the tristimulus colorimeter. After that we estimate the LED spectrum using a Gauss or Beta function, where the chromaticity coordinates and the channel values (X_{short}, X_{long}, Y and Z) are nearly the same. At the last phase the optimal matrix transformation can be determined for the estimated LED spectral power distribution using Gauss or Beta distributions. The estimation of LED spectra can be improved if we iterate this process. This method we call adaptive matrixing.

Table 1 shows average colorimetric errors for a number of coloured LEDs in case of using the tristimulus colorimeter in its traditional form (no matrixing), matrixing the signal of only the four fundamental output channels and using also the fifth channel. A tremendous improvement in measuring accuracy could be observed.

Table 1. Average colorimetric error for a number of coloured LEDs

LED		No matrixing	Using Adaptive Matrixing					
		Calibrated to CIE-A	4 channel			5 channel		
			Triangle	Gauss	Beta	Triangle	Gauss	Beta
450,0	$\Delta E^*_{a,b}$	27.40	0.91	1.65	0.56	0.14	1.56	0.06
523,2	$\Delta E^*_{a,b}$	7.30	2.83	2.93	2.63	2.33	2.85	2.25
526,8	$\Delta E^*_{a,b}$	7.63	0.98	2.39	0.87	0.79	1.93	0.67
573,6	$\Delta E^*_{a,b}$	9.56	2.43	2.85	0.97	2.00	2.51	0.70
605,4	$\Delta E^*_{a,b}$	6.07	0.92	0.93	0.73	0.74	0.34	0.32
619,1	$\Delta E^*_{a,b}$	6.95	0.93	1.18	0.59	0.31	1.06	0.09
619,4	$\Delta E^*_{a,b}$	6.93	1.32	1.77	0.60	0.24	0.81	0.20
641,9	$\Delta E^*_{a,b}$	7.93	1.94	2.00	0.65	1.45	1.86	0.47
Average		**9.97**	**1.53**	**1.96**	**0.95**	**1.00**	**1.61**	**0.60**
Std.dev		**7.12**	**0.77**	**0.73**	**0.69**	**0.83**	**0.85**	**0.71**

The advantage of this method is that the systematic error can be decreased already in case of a four channel tristimulus colorimeter, but it can be further improved using a 5th channel.