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APPLICATION OF DIFFUSE MEASUREMENT GEOMETRY IN THE EVALUATION OF PRINT QUALITY

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Abstract:

In print industry optical quality control mostly uses spectrophotometers with typically 45º:0 *geometry, bidirectional or circumferential illumination. Diffuse measurement geometry is usually applied to eliminate the effects of texture and gloss. Two cases are presented to demonstrate the applicability of diffuse geometry in case of printed substrates.*

In the first case study fiber coupled spectrophotometer is used with an integrating sphere and incandescent illumination. With such non-compact device the arrangement provides students with the opportunity of better understanding and experimenting. Reflectance spectra were measured in specular-included mode, results were compared to an industry standard instrument output. The inter instrument agreement was evaluated using the standard ΔE^*_{ab} *and the CIEDE2000 formulas. Threshold level agreement was found between the industry standard compact and the fibre coupled spectrophotometer which was assembled from individual components.*

Keywords: *spectrophotometer, fiber optics, diffuse geometry, integrating sphere*

1 INTRODUCTION

Reflectance spectrophotometers measure the amount of light reflected by a surface as a function of wavelength to produce a reflectance spectrum. Spectral data of an illuminated sample weighted by the standard colorimetric observer result in tristimulus values for the evaluation of sample color. Print industry uses portable or in-line spectrophotometers to determine spectral reflectance or colorimetric data of printed substrates. Most of the substrates have flat surface, while substrates with surface pattern are becoming more and more popular as printing technologies evolve.

The output of surface spectral measurements depend on irradiation and viewing geometry. The CIE (Commission Internationale de l'Eclairage, International Commission on Illumination) have defined four standard geometries. In these definitions the angular (spatial) distribution of the incoming and the observed light are specified.

In case of directional geometries the notation of the measurement geometry is illumination angle : observation angle, for example 0:45 means incoming light at 45º, observation along the surface normal, 45:0 in reversal . The alternative to directional irradiation is annular illumination denoted by 45ºa:0. Circumferential illumination is useful, when the specimen surface structure is directional making measurements dependent of angular position of the instrument.

Standard geometries for directional-hemispherical geometry are denoted by d_n:8, or its reversal 8:d_n, with subsript meaning that the specular component of the reflection is included (e.g. d_i:8º) or excluded (e.g. d_e:8º). [1]

Diffuse measurement geometry is implemented with an integrating sphere (or Ulbricht sphere) as an optical component (figure 1). It consists of a hollow spherical cavity with its interior coated for high diffuse (scattering) reflectivity, it has relatively small holes for entrance and exit ports. Light incident on the inner surface suffer multiple scattering reflections, the obtained spatial uniform radiation pattern shows no trace of the original angle. Optimally an integrating sphere eliminates spatial information while preserving the relative spectral power distribution. Edge shaping of the sample port is critical to ensure 180º field view of the sample.

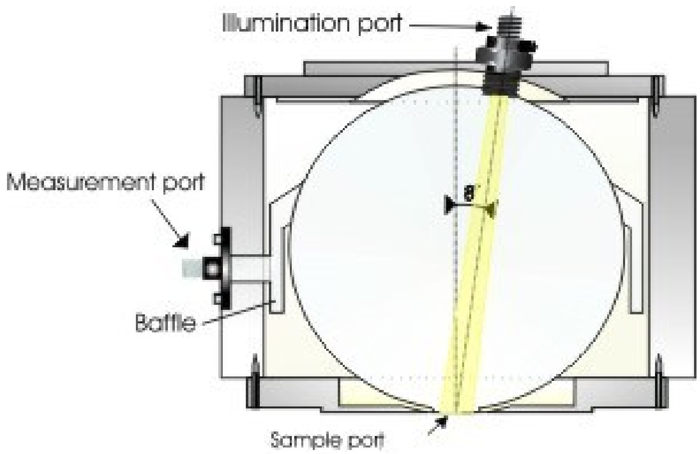

Figure 1: Integrating sphere for optical fibre coupled spectrophotometer system[2]

In print industry reflectance spectrophotometers offer the whole range of measurement geometries. Some are popular, industry standard devices, which have built in functions to calculate industry specific parameters from measured spectra. Such compact devices are useful in production, but offer less degrees of freedom in setting up a measurement and are not the best demonstration tools for students specialized for printing and media technology in higher education.

The aim of this study was to examine the usability of fibre-coupled spectrophotometer compared to a reference industry standard instrument.

2 EXPERIMENTAL

The reasonable expectation toward different instruments with the same optical geometry is that irrespective of the manufacturer they will give nearly the same results for the same set of samples.

The fibre optic spectrometer was AvaSpec-3648 symmetrical Czerny-Turner type with 3648 pixel linear CCD detector array and 16 bit A/D converter. The choice of diffraction grating (blazed at 500nm) and slit allowed for approximately 1 nm resolution.

AvaSphere-50-REFL type integrating sphere for reflection (250-2500nm wavelength range; 50mm diameter) with 10mm sample port, 2 SMA ports, the sample port on the side of the sphere (direct reflections from the sample are prevented by a baffle), the other port at 8º, for direct illumination.

A current stabilized halogen fan-cooled light source was used for illumination in the visible range and the near infrared. Direct illumination and indirect reflection (d_i:8º) geometry was used, a 600 micron diameter optical fibre coupled the light of the illumination and a 400 micron fiber connected the integrating sphere with the spectrophotometer. The typical integration time was 1500ms in this set-up.

The same diffuse white reference tile (WS-2) with approximately 98% reflectance was used for calibration of both instruments. The industry standard compact device used as reference was Xrite ColorEye XTH with pulsed Xenon illumination, a spectral range of 350-750nm and 10nm resolution. The instrument has two apertures, the one with 10nm was chosen for comparison with the fibre optic spectrophotometer.

Two test substrates with surface patter were chosen for the measurement: Valmex Airtex from Mehler Texnologies (280g/m²) which is a 100% polyester fabric coated on one side with acrylate for large area advertising, and a PVC net with 250g/m² grammage. A test chart with visual elements and uniform patches for measurement was designed and printed on the, substrates with a HP Scitex FB6100 wide format drop-on-demand inkjet printer.

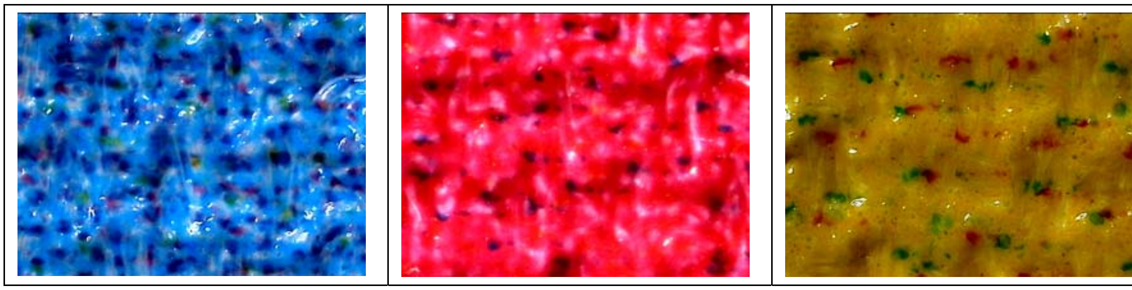

Figure 2: Microscopic images of cyan, magenta and yellow digital prints of coated polyester canvas

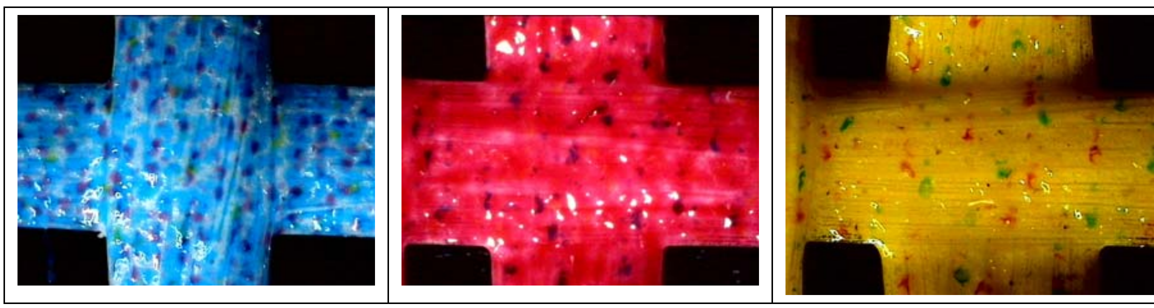

Figure 3: Close-up images of printed PVC net, cyan, magenta and yellow patches

3 RESULTS

Inter-instrument agreement was tested to prove the usability of the fibre coupled spectrophotometer as an alternative of the industry standard device. Samples of the test chart were measured on the different substrates. Black backing was applied as the background of the PVC net. Color differences were determined between the two set of measurement results (as illustrated in table 1 and 2 for both substrates). Because the calculated color difference ΔE^*_{ab} values were in the order of unit perceivable color difference, values were also determined with the CIEDE2000 formula [3] which predicts perceived color differences more accurately in case of $\Delta E^*_{ab}<5$.

Table 1: Inter-instrument agreement between industry standard and fibre optic spectrophotometer measured on printed polyester fabric substrate

	Industry standard s.meter			Fiber optic s.meter				
	L*	a*	b*	L*	a*	b*	ΔE^*_{ab}	ΔE^*_{00}
C	60,1	-9,8	-24,9	59,8	-9,7	-28,8	3,91	1,6
M	45,1	52,8	-2,2	43,3	53,4	-4,1	2,69	1,92
Y	79,6	-10,8	67,45	77,3	-10,3	64,8	3,54	1,75
K	30,7	2,77	0,4	29,8	2,4	0,2	0,99	0,86

Table 2: Inter-instrument agreement between industry standard and fibre optic spectrophotometer measured on printed PVC net substrate

	Industry standard s.meter			Fiber optic s.meter				
	L*	a*	b*	L*	a*	b*	ΔE^*_{ab}	ΔE^*_{00}
C	56,3	-23,1	-36,9	56,9	-20,74	-38,5	2,91	1,51
M	47,6	59,8	-1,6	48,3	61,7	-0,2	2,46	1,07
Y	82,3	-9,2	75,9	85,5	-8,7	78,7	4,28	2,26
K	31,2	1,1	3,8	30,9	0,9	2,7	1,16	1,01

Inter-instrument agreement was also determined in comparison with a device that has circumferential illumination, 45ºa:0 standard geometry (table 3). Although in this test the two instruments were produced by the same manufacturer, this comparison resulted in color differences well beyond the unit perceivable color difference.

Table 3: Inter-instrument agreement between industry standard devices with directional and diffuse measurement geometries from the same manufacturer, measured on printed PVC net substrate

	Canvas	PVC net
	ΔE^*_{ab}	
C	9,5	15,5
M	6,7	10,5
Y	9,7	17,8
K	12,5	16,1

4 CONCLUSION

In this study the inter-instrument agreement of an industry standard and a fibrer-coupled spectrophotometer with diffues geometry was compared on printed substrates with surface pattern. Threshold level agreement was found between the two devices. Comparison between directional and diffuse measurement geometry resulted in large color differences for printed substrates with surface pattern.

5 REFERENCES

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