The Effect of Sample Backing on the Accuracy of Color Measurement

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Keywords

Color difference, Backing, Conversion method

Introduction

Color is quantified by CIE colorimetry and color difference can be expressed quantitatively by ΔE (CGATS.5, 200x). Those who use colorimetry to specify color and compare color differences know that the magnitude of ΔE correlates to color difference of simple colors. But, many do not know that the same sample, e.g., a solid yellow patch, measured by the same instrument using a different sample backing could have a significant color difference.

ISO 5-4 (1995) specifies the use of black backing in color measurement for process control. Yet, white backing is preferred by professionals who make color measurement for device profiling. Such inconsistensies in color measurement conditions can cause obvious errors when comparing colors. For example, printers and customers compare how the colors match between proofs and press sheets. They may get a large ΔE and think that there is large color difference between the two compared samples, when in fact, the large ΔE is produced by the backing substrates, not the colors themselves.

To reconcile the effect of backing materials in color measurement, Hans Ott (2003) proposed an approach to convert the color values from one sample backing to another.

Objective

The objective of this study is to find out the magnitude of color difference due to sample backing for papers with different opacity, implement the spectral corrections as described by Hans Ott to account for the backing difference, and assess the effectiveness of the conversion method.

Measurement Device and Targets

In this research, we use Gretag SpectroScan to measure the IT 8.7/3 basic test target (182 patches). The target was printed on three different papers: coated paper (Consolidated Matte 80#), digital print paper (Hammermill laser print), and newsprint using a black and a white backing substrate.

System Noise Statistic

To evaluate the noise in the measurement device, we use two sets of colorimetric data measured from a single paper on the same black or white backing to calculate ΔE(Lab). The two sets of data are obtained in two days, and the measurement condition adheres to 0/45 geometry, D50 illuminant, and 2-degree observer. Thus, we obtain the measurement errors through ΔEs of the 182 color patches of the six samples.

Cumulative relative frequency (CRF) curves can be used for quantitative analysis of color difference (Chung, 2001). Figure 1 illustrates the six CRF curves of measurement errors derived from six samples. The shape of the six curves is identical, and all curves are close to each other, which show that the measurement errors from different samples are very similar In addition, the maximum ΔE is less than one. Therefore, we can derive a CRF curve of measurement error using the average values of the six measurement errors from the six samples .

Color Difference Due to Sample Backing

We compute the difference between two sets of data measured from a single paper in the same day, but on two different backing substrate, so that we can find how the sample backing affects the measured colorimetric values. For this study, we will compare the effects of sample backing to papers with different opacities.

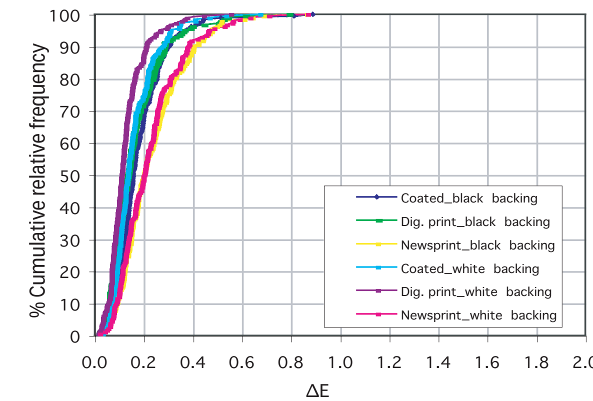

Figure 1. CRF curves of six measurement errors.

Opacity of paper can be defined as the percent ratio of the CIE Y of the paper measured on a black backing and the CIE Y of the same paper measured on a white backing (CGAT.5-200x). Table 1 shows the opacity for the three papers used in this work.

	Coated paper	Dig. print paper	Newsprint
Y(Black backing)	86.24	85.39	56.32
Y(White backing)	89.66	91.03	61.66
Opacity	96.19	93.80	91.34

Table 1 The opacities of three kinds of paper.

Figure 2 shows four CRF curves to express the system noise and the color differences of the three kinds of paper due to the sample backing. The curves indicate that ΔEs of the sampled paper are much higher than the system noise. In addition, the higher the opacity of the paper, the lower the ΔEs produced, i.e., there is less effect from backing substrate on the colorimetric data.

For example, newsprint has a ΔE of 4.45 at the 95 percentile, digital laser print paper has a ΔE of 2.88 at the 95 percentile, coated paper has a ΔE of 2.2 at the 95 percentile, and the system error has a ΔE of 0.37 at the 95 percentile.

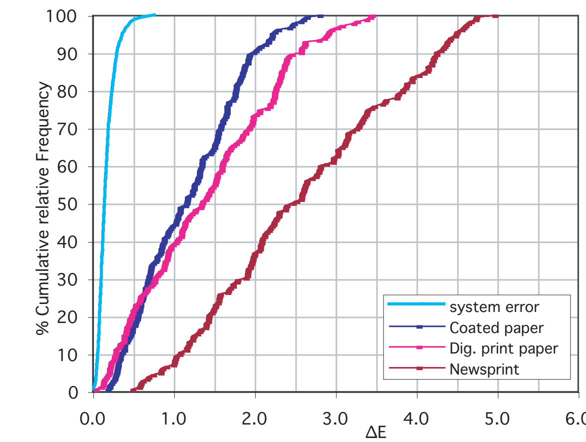

Figure 2 CRF curves of the three papers and system noise

Conversion from White Backing to Black Backing

According to the literature on conversion of color values for different sample backing (Ott, 2003), we can compute the reflection spectrum values of the samples with black backing from the white backing for 182 color patches on the three kinds of paper, using the formula:

$$R_{bi} = R_{wi}{}^{*} R_b / R_w \qquad (1)$$

with,

R_{bi}: Reflection-Spectrum for ink on a black backing

R_{wi}: Reflection-Spectrum for ink on a black backing

R_b: Reflection-Spectrum for the paper on the black backing

R_w: Reflection-Spectrum for the paper on the white backing

Figure 3 shows the reflection spectrum curves of yellow solid printed on the coated paper. We find that the calculated spectrum value with black backing is very close to the measured ones.

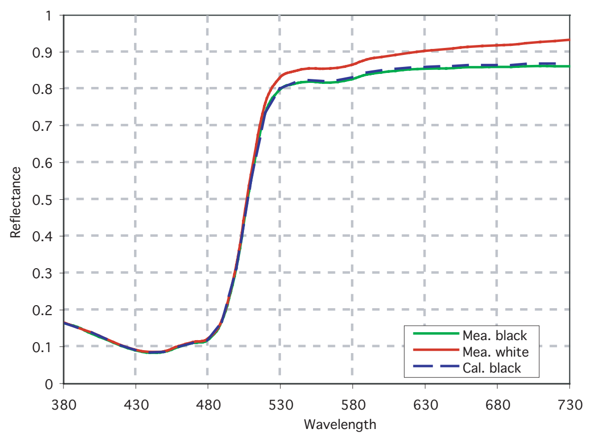

Figure 3 Yellow solid spectrum curves.

After we compute and obtain the spectrum values for 182 color patches printed on the three sample paper, we calculate the values of X, Y, Z and L, a, b for each color patch, using the spectral weights and X,Y,Z calculation equations provided in CGATS.5-200x and L, a, b calculation equations provided in Annex H of CGATS.5-200x for calculation of colorimetric values.

Conversion Method Assessment

We compare the calculated colorimetric values of each color on black backing with the measured ones, and obtain the ΔE for each color on the three kinds of paper. Figure 4, 5, and 6 use the CRF curves of ΔE to show the difference between measured data and calculated data of one paper on the same black backing substrate.

Figure 4 shows two CRF curves of ΔE of the coated paper and CRF curve of the system noise. ΔE is reduced to below 1.0, but it is not the same as the system errors. At the 95 percentile, the value of ΔE is reduced from 2.26 to 0.67. The % correction using the spectrum-based approach is equal to (2.26-0.67)/(2.26-0.37) or 84%.

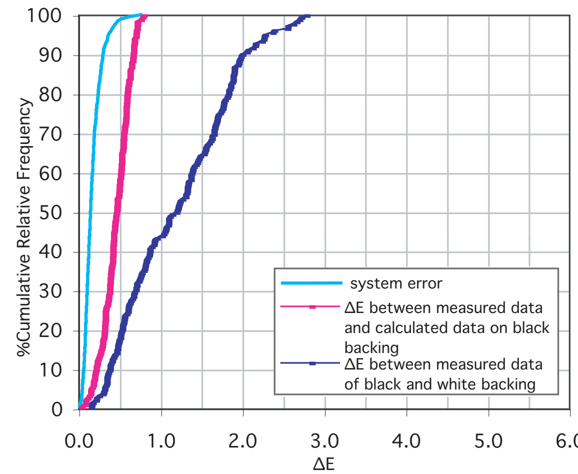

Figure 4 CRF curves of ΔE of Coated paper.

Figure 5 shows two CRF curves of ΔE of the digital laser print paper and CRF curve of the system noise. Here, we also find that ΔE is reduced greatly, but there is still a little difference from the system noise. At the 95 percentile, the value of ΔE is reduced from 2.86 to 0.87. The % correction using the spectrum-based method is 80%.

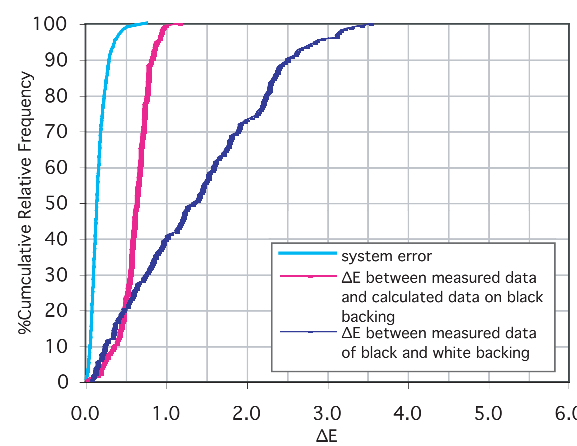

Figure 5 CRF curves of ΔE of digital laser print paper.

Figure 6 shows two CRF curves of ΔE of the newsprint and CRF curve of the system noise. In this picture, ΔE is reduced greatly, but the CRF curve of the reduced ΔE is not close to the one of system noise. The value of ΔE is reduced from 4.45 to 1.40 at the 95 percentile, and the % correction using spectrum-based approach is 75%.

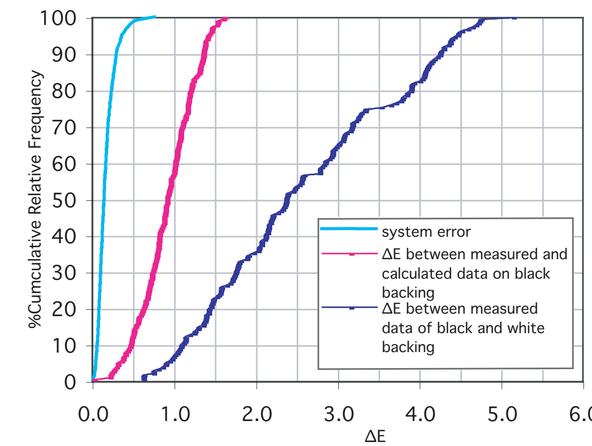

Figure 6 CRF curves of ΔE of the newsprint

From the above three figures, we learn that newsprint gets a largest reduction of ΔE from the conversion method. However, we find that ΔEs are still a little greater than the system noise; the difference of two colorimetric data obtained from two different backing substrate still exists.

Conclusion

From this study, we learn that backing substrate influences the colorimetric values and spectral data for color measurements, and paper with lower opacity will show more effect.

The analysis of this study also shows that the effect of backing substrate on paper can be reduced and corrected through the reflection spectrum conversion method proposed by Hans Ott, but it still cannot be eliminated completely due to uncertain reasons. Furthermore, as the opacity of paper decreases, the effect of backing substrates will increase.

Therefore, we should select the right backing substrate for different paper and adhere to the CGATS. 5 standard (NPES, 2003), which leads to the following: (1) white backing is recommended when the substrate opacity is below 95, (2) black backing shall be used while the substrate opacity is between 95 and 99 or when both side of the substrate are printed, (3) if the substrate opacity is equal to or greater than 99, it is considered opaque, and the backing used for measurement is not relevant.

Acknowledgments

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Literature Cited

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