

# Correcting Measured Colorimetric Data for Differences in Backing Material

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Keywords: Backing, Colorimetry, Measurement, Reflectance

## Abstract

The question of which backing to use when making spectral reflectance measurements has many answers depending on the application and perspective of those using the data. The densitometry standards all call for a black backing to minimize the impact of back printing and to minimize variability due to translucency effects and local variations in opacity and backing uniformity. The color management world finds more consistent results, between visual comparisons of proof and print, when using profiles based on white or self backing.

There have been no significant proposals of methods to convert colorimetric data measured with one backing to the values that would have been measured with a different backing. In a CGATS meeting in 2003, the late Hans Ott proposed a method using the ratio of the spectral reflectance of the substrate with the two backing materials of interest (the one used for data collection and the one for which data conversion was desired). In that same CGATS meeting, a method based on the use of the tristimulus values of the substrate over each backing was also proposed.

This paper summarizes both methods. It also compares the results of each using measurements of the IT8.7/3 basic data set data printed on coated paper, digital print paper, and newsprint.

## Introduction

When making spectral reflectance measurements, the question of which backing to use cannot be avoided. The sample being measured must rest on something.

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In an automated reader, this is a backing plate provided by the manufacturer and is usually either black or white. With hand-held instruments the choices are wider, and sometimes the backing is simply whatever is available. However, even with hand-held instruments the backing is generally a black or white reference and sometimes a stack of the printing substrate (self-backing).

There is considerable divergence of opinion about the best backing to use. The densitometry standards all call for a black backing to minimize the impact of back printing and to minimize variability due to translucency effects and local variations in opacity and backing uniformity. The color management world finds more consistent results between visual comparisons of proof and print when using profiles based on white or self backing.

Many users would like to be able to make one set of spectral measurements and use the resultant data to compute both density data and colorimetric data. This doesn't work if data based on two different backings are desired. It would be desirable to be able to use data based on measurements over one type of backing to predict the equivalent data that would have been obtained using a different backing.

There have been no significant papers that propose methods to convert spectral reflectance data, colorimetric data, or densitometric data measured with one backing to the values that would have been measured with a different backing.

In a CGATS meeting in 2003 the late Hans Ott proposed a method to estimate spectral reflectance data measured over one backing from data measured over a different backing. Although Han's method modified spectral reflectance data, it was primarily focused on adjusting the derived colorimetric data. In the same CGATS meeting McDowell proposed a correction method based on adjustment of tristimulus values.

The two methods are described in the following paragraphs along with a comparison of the results obtained with each method.

#### Ott Correction Method

The correction method proposed by Hans Ott was based on the assumption that the spectral reflectance of individual samples could be corrected by multiplying the spectral reflectance curve, wavelength by wavelength, by the ratio of the spectral reflectance of the substrate alone (i.e., in an area containing no printing) over each of the backing materials at the same wavelengths.

Once the adjusted spectral reflectance data is computed, the usual equations are then used to recompute the CIE X, Y, Z, and subsequent CIE L\*, a\*, and b\* values in the usual manner using the modified spectral reflectance data..

This can be expressed as:

$$R_{n2} = R_{n1} \times \left( \frac{R_{s2}}{R_{s1}} \right)$$

where:

$R_{n1}$  = Reflection spectra for sample n on backing 1,

$R_{n2}$  = Reflection spectra for sample n on backing 2,

$R_{s1}$  = Reflection spectra for the substrate alone on backing 1, and

$R_{s2}$  = Reflection spectra for the substrate alone on backing 2.

#### Tristimulus Correction Method

The tristimulus correction method is based on the observation that, when the deltas in CIE X, Y, and Z between measurements made over two backing materials (i.e., black and white) are plotted vs the X, Y, and Z values for measurements made over either material, the best fit result is approximately a straight line. At the lowest value of each tristimulus value, the delta between measurements made over the two backings is at or near zero. The maximum difference in measurement due to backing material characteristics is always at the maximum tristimulus value, which equates to a measurement of the substrate (usually paper) alone. Although these observations were made from plots of tristimulus values computed from measured spectral reflectance data, similar results would be obtained if tristimulus data were measured directly. Figure 1 shows a typical plot of the deltas vs. values for newsprint.

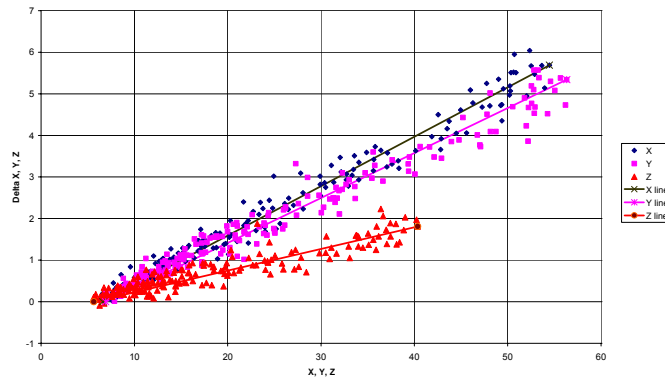


Figure 1 White-backing minus black-backing vs. data value

This implies that measurements made over one backing can be used to estimate the measurements that would be made over another backing by simply adding (or subtracting) a correction factor in X, Y, and Z. This correction factor is simply a proportional amount of the difference between measurements of the substrate alone over the two backings where the proportion added is defined by the value of X (or Y, or Z) on the first substrate compared to the minimum value of X and the value of X for the substrate alone.

This leads to a correction equation for X as follows:

$$X(n)_2 = X(n)_1 + (X(s)_2 - X(s)_1) * \frac{(X(n)_1 - X_{MIN})}{(X(s)_1 - X_{MIN})}$$

where

- $X(n)_1$  = Measured value of X for sample n over backing 1,
- $X(n)_2$  = Predicted value of X for sample n over backing 2,
- $X(s)_1$  = Measured value of X of the substrate over backing 1,
- $X(s)_2$  = Measured value of X of the substrate over backing 2, and
- $X_{MIN}$  = Minimum value of X which generally corresponds to a 4-color solid, which is patch ID 24 of the IT8.7/3 data set or patch ID 1286 of the IT8.7/4 data set.

For computation this equation can be rearranged as follows:

$$X(n)_2 = (X(n)_1 * (1 + C_1)) - C_2$$

where:

$$C_1 = \frac{X(s)_2 - X(s)_1}{X(s)_1 - X_{MIN}}$$

and

$$C_2 = C_1 * X_{MIN}$$

Corrections for Y and Z of the individual samples are accomplished in a similar manner and CIE L\*, a\* and b\* values are computed from the new tristimulus values.

## Comparison of Results

Kong measured the spectral reflectance of samples of the IT8.7/3 basic data set (patch IDs 1 through 182) printed on coated paper (Consolidated Matte 80#), digital print paper (Hammermill Laser Print) and newsprint using both a black and a white backing. Her measurements were made in accordance with CGATS.5 using backings that conformed to the requirements specified in that standard.

Using the Ott method and the spectral reflectance data measured over the white backing, she also calculated the predicted reflection spectra for the black backing condition. CIE X, Y, Z and L\*, a\*, b\* data were computed from the measured over-white spectral data and from both the measured over-black and predicted over-black spectral data.

These results were initially reported in the June 2003 issue of "Test Targets 3.1", an RIT School of Print Media publication.

Using the CIE X, Y and Z values computed from the over-white spectral reflectance data, the over-black values were computed using the tristimulus technique. CIE L\*, a\*, and b\* data were computed for all cases from the tristimulus values.

Measurement uncertainty was estimated for each paper type by measuring the same samples on two different days over each backing. The differences between the two measurements on each backing were computed and merged with the black-to-white backing differences to give a pooled estimate of the measurement uncertainty.

Figures 2 through 4 each show cumulative frequency plots of the following  $\Delta E$  calculations:

- a. Between the measured over-black and the measured over-white,
- b. Between the measured over-black and the predicted over-black using the Ott method,
- c. Between the measured over-black and the predicted over-black using the tristimulus method, and
- d. The pooled estimate of measurement uncertainty.

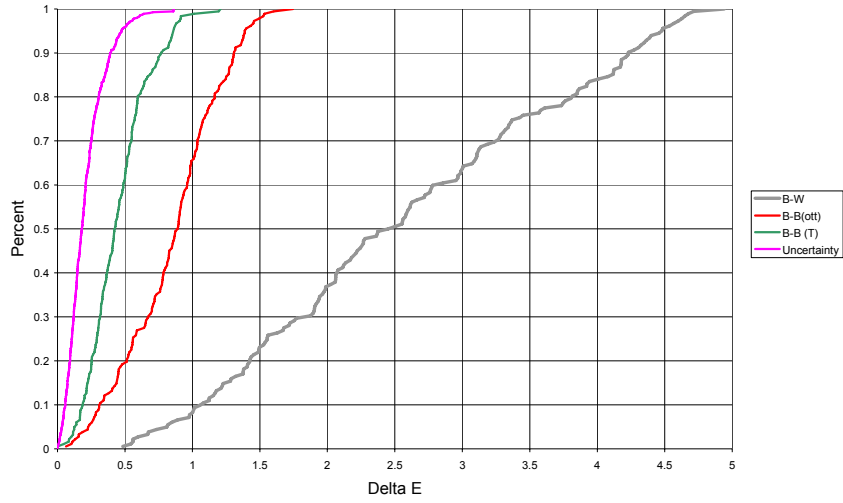


Figure 2 – Newsprint

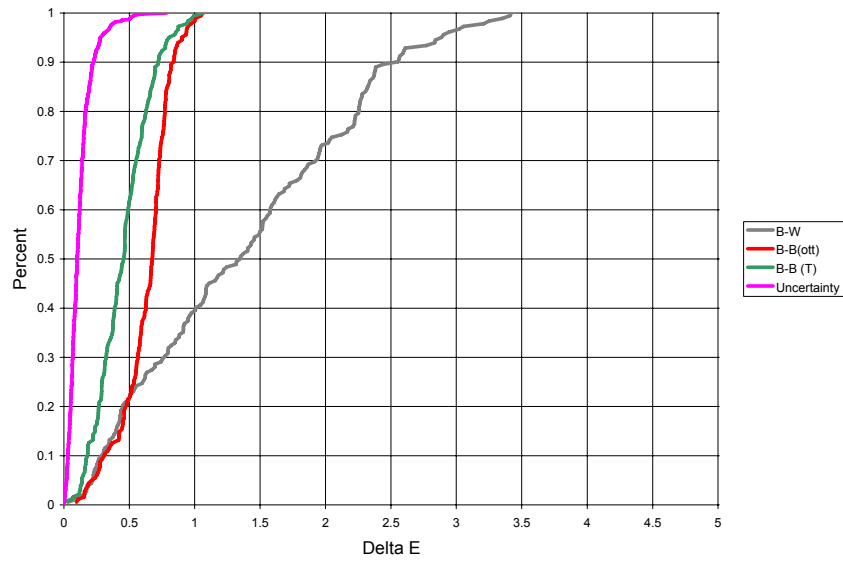


Figure 3 – Digital print paper

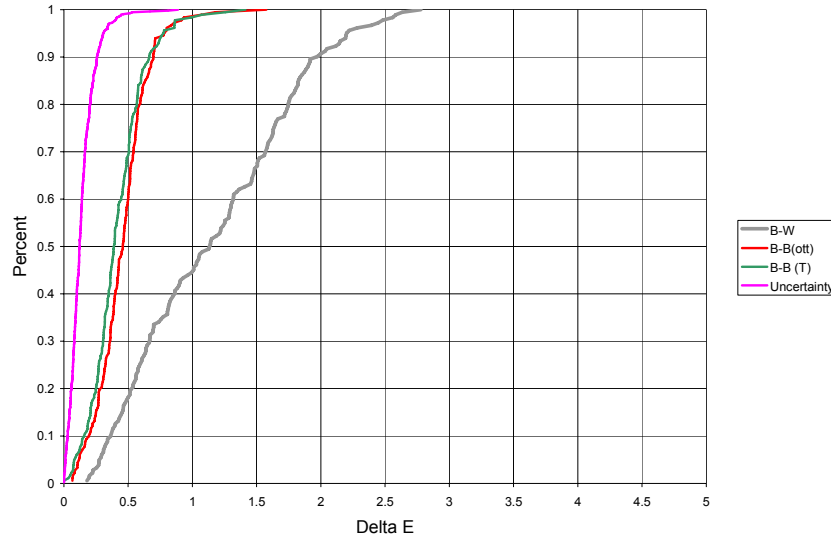


Figure 4 – Coated paper

As can be seen from the figures, for all three materials tested, either the Ott method or the tristimulus method were a significant improvement over no correction. In all three cases studied, the tristimulus method gave a better prediction of the measured data. For these materials the 50th percentile of the predicted vs. measured over-black data was approximately 0.4 delta E and the 98th percentile was approximately 1.0 delta E. These results seemed essentially independent of the printing substrate for the three substrates tested. These values were approximately twice the noise estimate in each case.

One of the additional benefits of the tristimulus computational technique is that the only additional data needed is the tristimulus values of the substrate measured over the second backing material. It is anticipated that, given additional testing, this approach may eliminate the need for multiple measurements, over various backing materials, of printed characterization targets.

A recommendation is being made to CGATS and the ICC that for all published characterization data, the tristimulus values of the substrate measured over a standard white backing and/or a standard black backing be included as part of the data set.

## Discussion

Although a detailed theoretical analysis has not been done of either correction method, nor of the basic halftone reflectance model itself, some observations are possible. We know from the work of Neugebauer and others, that in its simplest version the halftone model must take into account the color of the three chromatic inks, the color of the three two-color overprints, the color of the black ink, and the paper white. Changes in the substrate reflectance caused by a change in backing material will clearly affect the reflectance of the substrate alone (which is the white in the Neugebauer model) more than the other printed areas.

The Ott correction method assumes that all reflectances are changed in the same proportion as the change in the substrate reflectance.

The tristimulus correction technique adds a correction factor roughly in proportion to the equivalent amount of paper showing. To a first approximation the maximum value of X, Y, or Z represents only substrate and the minimum represents solid ink coverage in the spectral region associated with that function. Therefore,

$$1 - \frac{(X_n - X_{MAX})}{(X_{MIN} - X_{MAX})}$$

(or Y, or Z) is an estimate of the apparent tristimulus dot area. This is very similar to the function used to compute the correction factor.

## Conclusions

Clearly, if we were dealing with continuous tone rather than halftone image data we would expect different results. Obviously, the tristimulus correction technique is only an approximation. For many applications it may be "good enough". For others, measurements on specific backings will be required based on the requirements of standards, user preferences, and understandings of color management, and colorimetric and densitometric process control yet to be defined.

## Bibliography

Test Targets 3.1, June 2003, An RIT School of Print Media publication

CGATS.5-2003, Graphic technology — Spectral measurement and colorimetric computation for graphic arts images