Method for Calibration of a Printing System With Digital Data Using Near-Neutral Scales

David Q. McDowell

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Abstract

At its fall 2006 meeting, ISO TC130 (Graphic technology) agreed to create a Technical Specification with the title "*Graphic technology Method for calibration of a printing system with digital data*". This specification, ISO 10128, will include the description of three methods which are generally identified as 1) using tone value increase, 2) using near-neutral scales, and 3) using ICC (device link) profiles. The initial work that prompted this TC130 activity was work being done in the United States by the IDEAlliance Print Properties Committee as they were developing the GRACoL and SWOP printing specifications. Their activities have focused on the use of near-neutral scales to develop four individual one-dimensional correction curves that are used to modify content data (often called plate correction curves) during digital plate-making. Based on this work, the US has agreed to provide the input to the portion of the proposed ISO Technical Specification dealing with the use of near-neutral curves. This paper describes the techniques being proposed by the US for inclusion in ISO 10128.

Introduction

As the printing and publishing world has embraced the use of digital data and the preparation of printing plates directly from digital data (often referred to as computer to plate or CTP), it has struggled to find ways to take better advantage of the electronic data manipulation opportunities offered. When traditional halftone film was the medium of exchange of final material and the input to the printing plate and press operation, the primary methodology available to the printer to match industry aims and standards was to force the press, ink and paper to be as close as possible to the references upon which the printing standards were based. Today, with digital data input, it is recognized that modification of that digital data can be used to compensate (adjust) for some of the differences in press, ink and paper between various printing sites and between the actual conditions at a specific site and the reference or standard printing condition.

As part of this digital revolution, the printing industry (and its standards activities) have begun to establish reference characterization data corresponding to various printing standards and conditions. Characterization data is generally defined as the relationship between the CMYK digital input values (in the data file exchanged) and the measured colorimetric values for the color printed in response to these values. When the printing conditions to be used are defined as a printing standard, these are referred to as standard or reference characterization data.

At its fall 2006 meeting, ISO TC130 (Graphic technology) recognized the need to formalize methods of accomplishing these modifications of digital data to allow the combination of modified digital data and a particular printing system to better match a reference or characterized printing condition. TC130 has identified three general methods by which compensation for differences in printing conditions can be accomplished. Two of these make use of individual one dimensional transforms for each printing channel, but differ in the method by which these transforms are determined. These are referred to as the tone value increase method and the near-neutral tone scale method. The third method makes use of multi-dimensional transforms in the form of International Color Consortium (ICC) device link profiles.

It was recognized that these are not competitive solutions, but each have different strengths and weakness in individual workflow applications. The choice of the approach used to best take advantage of this "new" capability, available to the industry through the use of digital data, is the responsibility of the individual printing facilities and trade associations involved.

The basic assumption behind the use of characterization data and these correction techniques is that a printing process can be repeatedly restored to a prior printing condition and that condition can be maintained both within a run and between runs. A variety of process control methods can be used to achieve this repeatability. Clearly solid ink density and tone value increase based on the specific materials involved and tied back to the conditions established during characterization, are common process control tools that are used in addition to these press calibration techniques.

It was agreed that Technical Specification ISO 10128, *Graphic technology Methods for calibration of a printing system with digital data* would be created to document these three methods.

The work that prompted this TC130 activity was work being done in the United States by the IDEAlliance Print Properties Committee as they were developing the GRACoL and SWOP printing specifications and associated color characterization data.. Their activities have focused on the use of near-neutral scales to develop four individual one-dimensional correction curves that are

used to modify content data (often called plate correction curves) during digital plate-making. Based on this work, the US agreed to provide the input to the portion of ISO 10128, dealing with the use of near-neutral curves. It is that input that is the subject of this paper.

Overview

Printing standards, in general, specify the ink and paper to be used and the process control parameters in colorimetric terms. Where the inks are well characterized densitometric aims may also included for reference. The ISO 2846 series of standards provides the mechanism to specify the color and transparency of the ink. Specification of paper is not well defined and is generally limited to a specification of its colorimetry, translucency, grammage, and reference to industry grades or classifications.

The outer gamut of the printable color volume is defined by the combination of the paper colorimetry, the color of the solids and of the two and three color solid overprints. These are included in the printing definitions defined in the ISO 12647 family of standards and are typically also included in other printing specifications.

Where printing standards or characterization data were based on practical printing tests it has always been assumed that if the outer gamut of the printing volume was correct, matching the tone value increase (we used to call it dot gain) of the individual colors to that of the reference printing specification was the key to matching the within-gamut relationship of color scales and overprint colors. Today, with full sets of color characterization data we realize that that is often not sufficient.

While the simple matching of tone value increase, is adequate in many situations, it only takes into account one of the three principal variables that impact the color of three and four color over-prints. While tone scale clearly is the most significant, the printed color is also impacted by ink-trapping, ink transparency and ink-water-paper interaction. These can vary between the press, ink and paper used to create a reference printing condition (or data manipulations steps) and its characterization data and the press, paper and ink used for the production printing even when all elements meet their individual .specifications within tolerance.

A comparison of the colorimetric data of the reference characterization data and that of the intended production printing for a reference near-neutral scale allows individual transforms to be determined for each ink channel. While similar to the concept of matching individual tone value increase curves, computation of the necessary correction curves for each channel based on the near-neutral scales

provides the ability to better compensate for those secondary variations that can impact overprint conditions.

In addition, where the reference characterization data used has been designed to produce good gray balance for a reference near-neutral scale this approach also allows the printing process to be monitored using gray balance in addition to, or in place of, using tone value curves and tone value increase.

Reference Data

The use of near-neutral scales to determine the required tone value correction curves makes use of any available reference characterization data. As noted above if the characterization data used has been designed to produce good gray balance for a reference near-neutral scale use of such characterization data also allows process control based on gray balance.

In addition to the reference characterization data a predefined near-neutral scale is used. Table 1 lists the CMY values recommended for such a scale. The tone values of this scale are reported to two decimal places because most characterization data is recorded as 8-bit per channel data and these values correspond to the quantization intervals associated with 8 bit data. As the colorimetric data to be associated with this neutral scale is usually computed or interpolated from color characterization data this minimizes an additional set of rounding errors.

Press Evaluation

Before the four one-dimensional correction curves used to digitally calibrate the press (i.e., modify the input data) can be determined, it is important to measure press performance using the inks and paper type specified for the reference printing condition being matched. Because the ink, paper press combination being used may not result in solids that exactly match the colorimetry specified, it is important to determine the local process control aims that provide the closest match to the aims.

This can be achieved by printing an ink film thickness series (what most of us call a density series) for each ink on the reference paper either by tagging on to the end of a production printing job using the same materials or by a specific test. The key issue is that it is important to measure and compute both density and colorimetry over a varying range. The difference in color (the deltaE between the color achieved and the aim value) can then be used to select an aim for process control. These aims represent the best that can be achieved with the ink, paper, and press being used to match the colorimetry of the aim solids. If during this test the two-color overprints do not match the colorimetry specified within

Table 1 Reference near-neutral scale

Step	Cyan tone value	Magenta tone value	Yellow tone value
1	0	0.00	0.00
2	1.96	1.18	1.18
3	3.92	2.75	2.75
4	5.88	4.31	4.31
5	7.84	5.49	5.49
6	10.20	7.45	7.45
7	14.90	10.98	10.98
8	20.00	14.90	14.90
9	25.10	18.82	18.82
10	30.20	23.14	23.14
11	34.90	27.06	27.06
12	40.00	31.37	31.37
13	45.10	35.69	35.69
14	49.80	40.00	40.00
15	54.90	45.10	45.10
16	60.00	50.20	50.20
17	65.10	55.29	55.29
18	69.80	60.39	60.39
19	74.90	65.88	65.88
20	80.00	71.76	71.76
21	85.10	78.04	78.04
22	89.80	84.31	84.31
23	94.90	92.16	92.16
24	98.04	96.86	96.86
25	100.00	100.00	100.00

the tolerances given (the tolerances in ISO 12647 are often used as a guide) then the inks or process should be investigated and the press evaluation not be completed until both solids and two color overprints are achieved within specified tolerances.

Once the printing conditions are established that match the colorimetric, aims for the boundary colors, an ISO characterization test chart (ISO 12642-1 or preferably ISO 12642-2) can be printed. Measurement of the printed image of this chart gives a set of characterization data that defines the press characteristics within the best match that can be achieved to the gamut of the reference printing condition.

Determination of Correction Curves

Given the reference characterization data a wide variety of color analysis tools can be used to determine the CIELAB values associated with the C, M, and Y

tone values of the near-neutral scale (or any other C,M,Y triplet). In addition, the IDEAlliance Print Properties Committee is recommending that the colorimetric values associated with this scale be included as part of the documentation associated with characterization data. This has been done for the three Technical Reports in preparation by CGATS which document the new GRACoL and SWOP characterization data.

The same color analysis tools can be used with the characterization data for the printing system being calibrated to determine the C, M, and Y tone values needed to match the colorimetry of the near-neutral scale or the reference printing condition being matched.

The differences between these tone values required by the printing system to match the colorimetry of the steps of the near-neutral scale and the C, M, ad Y input values of the near-neutral scale (shown in Table 1) create the correction curve needed to accomplish the necessary calibration.

In a similar, but simpler fashion, a correction curve can be computed for the black channel. The tone values used for the black are the same as the tone values for cyan used in the near-neutral scale.

Press Calibration

Press calibration is simply the systematic application of the correction curves determined above to all content data on an individual C, M, Y and K channel basis. This is typically accomplished using plate-setter curves, but may also be accomplished in the RIP or using any other digital data manipulation step available in the particular workflow being used.

Process Control

As mentioned above, where the reference characterization data has been prepared to produce good gray balance for a reference near-neutral scale the printing process can be monitored using gray balance in addition to, or in place of, using tone value curves and tone value increase.

Where this method of process control is used it is useful to print the near-neutral scale as a control bar along with a single color black scale that matches the tone values shown for cyan in the near-neutral scale.

Where this is being done the concept of neutral print density (NPD) is a useful tool to monitor the lightness relationship of the neutral curve. NPD is defined using the equation

$$NPD = LOG_{10}(Y_S) - LOG_{10}(Y_P)$$

Where
Y_S is the CIE Y value of the sample, and
Y_P is the CIE Y value of the paper or substrate.

It is important to note that NPD is mathematically equal to paper relative visual density as defined in ISO 5-3.

This allows the near-neutral scale to be monitored using colorimetric data. Similar computations and control can also be accomplished for the black scale using colorimetric data.

Summary

There are no hard and fast rules which dictate which method of press calibration is preferred. However, in general the use of device-links as the calibration method will find wider applicability in those printing and proofing technologies that use colorants that differ from the traditional inks specified in ISO 2846. It is also expected that the color characterization of printing done with extreme non-periodic screens will differ sufficiently from traditional characterization data that the use of device-links as the calibration method will be required.

The use of either the tone value increase curve or the near-neutral scale calibration techniques will find greatest applicability in those printing processes where the printing colorants and processes are similar to the processes and colorants used to create the reference printing condition.

We believe that the near-neutral scale method will offer advantages over the tone value increase approach. In particular this method will offer the greatest advantage where it is combined with characterization data that produces good grey balance for the tone values of the reference near-neutral scale and grey balance is used as a process control tool.

There may also be some situations where the most effective calibration can be achieved by a combination of the application of neutral scale tone value correction curves followed by the application of ICC device link profiles.

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