The Effect of Substrate Correction on Printing Conformity

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Abstract

Printing has become more and more of a manufacturing process. As a manufacturing process, the goal is to meet specifications. When printing on nonconforming papers, printing conformity is jeopardized. The use of the substrate-corrected colorimetric aims (SCCA), as specified in ISO 13655, represents a solution. But benefits of SCCA are not fully understood and the solution not widely adopted in the printing industry. A research question arises, “What is the effect of substrate correction on dataset conformity for a large number of offset, digital printing, and proofing jobs?” To answer the question, this research uses a database of 60 jobs to study the effect of substrate correction on printing conformity where the white points of the dataset and the color of the printing paper vary. The results show that substrate-corrected color aims (SCCA) enables more job conformance and reduces failed jobs for both conforming and non-conforming papers.

Introduction

When printing is managed as a graphic arts process, acceptability is not explicit until the customer subjectively signs off at the press site. When printing is managed as a manufacturing process, acceptability is specified objectively based on standards.

As the printing industry migrates toward the manufacturing model, a number of conditions must be fulfilled in order to enable an efficient, productive, and profitable printing operation. These conditions include (1) applicable printing standards that communicate requirements objectively, (2) measurement devices that indicate product characteristics (CIELAB) and process behaviors (TVI, gray balance), and (3) process automation and control efforts that demonstrate printing conformity. If one or more of the above conditions is not fulfilled, the benefits of a manufacturing process will suffer.

Problem Statement

Printing specifications include aims and tolerances of material, process, and product characteristics. Customers prefer printing on “clean and bright” papers. These papers, containing optical brightening agent (OBA), do not conform to printing specifications. They also affect printed colors. Thus, there is a dilemma between meeting print buyer’s paper preference and meeting printing specifications.

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**Literature Review**

When measurement backing causes color measurement difference of reflection print, ISO 13655 (2009) specifies the tristimulus linear correction method to reconcile the difference. Later, the tristimulus linear correction method was extended to correct paper color difference between target and sample (McDowell, 2011).

The calculation of the substrate-corrected colorimetric aim (SCCA) is carried out by (a) converting CIELAB of the target dataset to CIEXYZ (D50, 2 degree), (b) converting the white point of the sample from CIELAB to CIEXYZ, (3) computing the substrate-corrected CIEXYZ using the tristimulus linear correction, and (d) converting the substrate-corrected CIEXYZ back to CIELAB.

Previous studies (Chung, 2013, Chung and Tian, 2011) showed that printed solids and gray balance conformity are affected by color of the substrate. The use of the tristimulus linear correction to modify printing aims (SCCA) improved the overall color conformity.

ISO 15339-1 (2014) is the first ISO standard that specifies the use of the tristimulus linear correction to correct substrate-induced colorimetric difference. CGATS TR016 (2012) is the first tolerance specifications for dataset conformity assessment. CGATS TR016 is based on ∆E00 as the metric with a multi-level tolerance scheme. In this research, we will focus on the effect of SCCA in assessing deviation conformity of a job.

Using substrate-corrected colorimetric aims (SCCA) to meet printing specifications represents a solution. But SCCA is not widely understood and adopted in the printing industry. The research question of interest is, “What is the effect of substrate correction on dataset conformity for a large number of offset and digital printing jobs?”

**Methodology**

This research begins by collecting 60 jobs, identified by ID numbers only, from a wide range of sources not to be named. These jobs contain CIELAB measurement values of the ISO 12642-2 target and their target datasets.

The next step is to analyze the deviation conformity by job according to CGATS TR016 (2012) with SCCA and without SCCA. Deviation conformity by parameter (dataset, CMYK solids, CMYK midtone tints, and CMY triplet) are also computed between measurements and the substrate-corrected aims and their conformity level determined according to CGATS TR016 (2012).

The last step is to analyze the effect of SCCA on deviation conformity of the database.

**Results**

This section analyzes conformity levels achieved by all jobs between two colorimetric aims (published and substrate-corrected). We then analyze how paper colors vary and their influence on conformity assessment.
Conformity Outcome of the Database by Job

Figure 1 illustrates the conformity outcome of the database by job according to the CGATS TR016 (2012) scheme. A general observation is that the use of SCCA raises the overall conformity level of the jobs in this database and reduces the number of failed jobs.

![Figure 1](image)

Figure 1. Conformity assessment outcome of all jobs

Conformity Outcome of the Database by Parameter

By analyzing each of the 10 normative requirements we can get a better understanding of the interaction between the SCCA process and the individual requirements. Looking first at the requirement to match the IT8.7/4 data set (Figure 2, left) and the requirement to match the CMY triplet (Figure 2, right), we can see that SCCA has a positive effect on both parameters.

![Figure 2](image)

Figure 2. Conformity assessment outcome by dataset (left) and CMY triplet (right)

Figure 3 illustrates the conformity assessment outcome of CMYK solids. SCCA benefits CMY solids except the black solid. This result is expected because the color of the substrate impacts the color of the printed solids (the XYZ values) in the areas that the ink does not absorb light. Only the black ink absorbs all regions of light.
SCCA benefits the midtone conformance (Figure 4) more than it does in the solid conformance because there is more unprinted paper visible in the midtone area.

**Analysis of Paper Color**

In the database, GRACoL (2006) and Fogra 39 are used as the dataset aims. The white points in these two datasets are the same (95L*, 0a*, -2b*). Figure 5 shows a*b* plots of all 60 paper colors. The target aim (0a*, -2b*) is shown as a red dot. The tolerances (+/- 2Δa*, +/- 2Δb*) according to ISO 12647-2, are shown as dotted lines.
Figure 6 illustrates the L* distribution of all 60 papers with the aim (95L*), as a red dashed line, and tolerances (+/- 3 ΔL*), as black dotted lines. There are more papers with darker shades than there are papers with lighter shades than the target.

By analyzing the paper color conformity according to the ISO 12647-2, there are 33 jobs conformed and 27 jobs not conformed.

Paper is the fifth color that influences printed color using CMYK process inks. This raises an interesting question, “What are the effects of substrate correction on printing conformity between non-conforming papers and conforming papers?”

**Conformity Outcome of the Database with Conforming Paper**

Figure 7 illustrates the conformity assessment outcome of the 33 jobs using conforming papers according to TR016. We can see that SCCA increases Level A conformance more while decreases job failure. Based on this finding, we can conclude that substrate correction benefits job conformity when conforming substrates are used.
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Figure 7. Conformity assessment outcome of conforming papers (n=33)

Conformity Outcome of the Database with Non-conforming Paper

Figure 8 illustrates the conformity outcome of 27 jobs using non-conforming papers per ISO 12647-2. There are a few Level A conforming jobs. SCCA increases more Level B and Level C conformance while decreases failure jobs. We can also conclude that substrate correction benefits job conformity when non-conforming substrates are used.

Figure 8. Conformity assessment outcome of non-conforming papers (n=27)

Discussion

Printing conformity as a function of paper conformity and press calibration

Printing conformity to dataset is affected by at least two factors. A primary factor that causes non-conformity in process color printing is printing calibration (ISO/TS 10128, 2009). A secondary factor is the color difference between the white point of the dataset and the printing paper. In this research, we studied the effect of press calibration and substrate correction in terms of (1) job using conforming paper and the press is calibrated, (2) job using non-conforming paper and the press is calibrated, and (3) job using conforming paper and the press is not calibrated.

Case 1 - Job using conforming paper and the press is calibrated

Case 1 (ID #4) is a print with a conforming substrate that, although conforming, does not exactly match the white point of the data set. Figure 9 contains six graphs. Together, they
describe how substrate correction works in the tristimulus (X, Y, Z expressed as percentage) color space. Specifically, the three graphs at the top row show the amount of linear correction according to the white point difference between the dataset and the printing paper. A conforming paper shows small amounts of ∆X, ∆Y, and ∆Z (expressed as percentage) in the top row of Figure 9.

![Figure 9. Effect of the tristimulus linear correction – Case 1](image)

The three graphs at the bottom row of Figure 9 show the deviation between the measurement and the two dataset aims. The color plots are color differences without SCCA and the gray plots are with SCCA. When the deviation is small, the plots are clustered around the horizontal axis indicating good press calibration.

Case 1 shows good press calibration. It also shows that SCCA further improves the conformity in the highlight region of the color space.

**Case 2 – Job using non-conforming paper and the press is calibrated**

Case 2 (ID #21) is a print with a non-conforming substrate. In this instance, the non-conforming substrate is CCNB or Clay-coated News Back with a low L* value (90L*).

![Figure 10. Effect of the tristimulus linear correction – Case 2](image)

Figure 10 (top row) indicates that larger amounts of correction are called for due to lightness difference between CCNB (90L*) and the dataset white point (95L*). Figure 10 (bottom row) indicates that the job failed if the substrate corrected color aims are not
used. SCCA removes the paper color difference, improves the conformity in the highlight to midtone region of the color space, and changes the conformity assessment outcome.

**Case 3 – Job using conforming paper and the press is not calibrated**

Case 3 (ID #26) is a print using conforming paper, as indicated by small amount of corrections in Figure 11 (top row).

Figure 11. Effect of the tristimulus linear correction – Case 3

Figure 11 (bottom row) shows large color difference due to poor color calibration. In other words, SCCA can remove the paper-induced color difference, but cannot change the conformity assessment outcome when the printing system is not calibrated.

**Relationship between paper color difference and printing conformity**

From an operational point of view, substrate correction is beneficial to printing conformity regardless paper conforms to standards or not. We may also want to know, “What is the upper limit of the substrate difference that a job can conform to dataset with SCCA?” Figure 12 illustrates how job conformity relates to paper color difference.

Figure 12. Job conformity as a function of paper color difference

There are 9 jobs in the database that meet Level A conformity and the substrate color difference among these jobs is up to 2.5 $\Delta E_{00}$. There are 22 jobs in the database that meet Level A and Level B conformity and the substrate color difference among these jobs is
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up to $5 \Delta E_{00}$. There are 41 jobs in the database that meet Level A, Level B, and Level C conformity and the substrate color difference among these jobs is also up to $5 \Delta E_{00}$. Thus, we can conclude that substrate correction is beneficial to printing conformity when substrate difference is up to $5 \Delta E_{00}$.

Conclusions

This research tackles a dilemma between meeting print buyer’s paper preference and meeting printing specifications. It used a database of 60 jobs to study the effect of substrate correction on printing conformity where the white point of the dataset and the color of the printing paper vary. The overall results show that substrate-corrected color aims (SCCA) enables more job conformance and reduces failed jobs for both conforming and non-conforming papers.

The effect of SCCA may be summarized as follows: (1) When a job using conforming paper and the press is calibrated, it will meet the conformity requirements and the effect of SCCA is noticeable, but negligible; (2) When a job using non-conforming paper and the press is calibrated, SCCA can remove the paper color difference and change the conformity assessment outcome of the job; and (3) When a job using conforming paper and the press is not calibrated, it will fail the conformity requirements regardless of the substrate is color corrected or not.

The results show that when the press is calibrated, which should be the case in a print manufacturing process, the SCCA method removes the paper color difference and improves the outcome of conformity assessment.

More and more non-conforming papers with OBA proliferate in the printing markets. Paper color introduces bias in process control and jeopardizes conformity assessment. It is imperative that printing standards specify the substrate correction method to enable printers to print to the substrate-corrected color aims.

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