

Predicting Pictorial Color Image Match

Robert Chung* and Wuhui Liu**

Keywords: Color, Match, Subjective, Quantitative

Abstract

Pleasingness is key to color reproduction. Pictorial color image match is key to digital color proofing. Different color proofing approaches are deployed in the color proofing market. The objective in this study is to evaluate if there are real differences among various color image adjustment methods. In doing so, an offset printed color reproduction serves as the reference. Different image adjustment techniques, including device calibration and color management, were implemented with the use of an inkjet proofer. Subjective evaluation of color image match between color proofs and the offset reference was conducted in a previous study. This paper describes the use of color chart, color measurement, and data analysis techniques in predicting pictorial color image match between proofs and the offset reference quantitatively.

Introduction

Printing standards, computer-to-plate technology, and color management change how we produce color proofs. In this instance, printing standards, such as ISO 12647-2, SWOP and GRACoL, define what numbers the press shall print to. Computer-to-plate technology eliminates film-based color proofing technology. Device calibration and color management enables digital color hardcopy devices, such as inkjet printers, to produce color proofs simulating how color images look like prior to presswork. The color match is metameric. Thus, color measurement condition and visual assessment are fixed at D50.

In an earlier research, we established the print reference by printing test images using the Heidelberg Speedmaster 74 sheetfed offset press (Chung, 2007). We prepared five Epson inkjet proofs using five color image adjustments, i.e., (A) by gradation, (B) by chroma, (C) by tone reproduction and gray balance, (D) by color conversion via profile connection space (PCS), and (E) by device link profile.

* RIT School of Print Media, Rochester, NY, USA

** Wuhan University, Wuhan, HuBei, PRC

These color proofs were visually evaluated in reference to the press sheet by means of paired comparison. Five of the 20 PCRI images were used in the paired comparison study (Figure 1). The subjective ranking of color image match between proofs and press, from best to worst, is (E) device link, (D) PCS, (C) tone reproduction and gray balance, (A) gradation, and (B) chroma.



Figure 1. Pictorial color reference images

A pictorial digital color image contains multi-million bytes of picture elements. A color chart only contains a limited number of color patches. This research asks the following research questions: (1) To what extent, the quantitative analysis of a color chart correlates, thus, predicts visual comparison of proof and print? (2) To what extent, the composition of the color chart impacts the color difference analysis, thus, its usefulness in predicting pictorial color image match between proof and print?

Methodology

This research compares the use of two synthetic color charts for quantitative color difference analysis to predict pictorial color image match. The first color chart is the IT8.7/3 basic chart, a 182-patch color chart (Figure 2). It can be characterized as a colorant-based color chart in that it contains C, M, Y, K ramps, R, G, B overprints, white, CMY neutrals, 3-color black, and 4-color black that define the color gamut of a printing device.

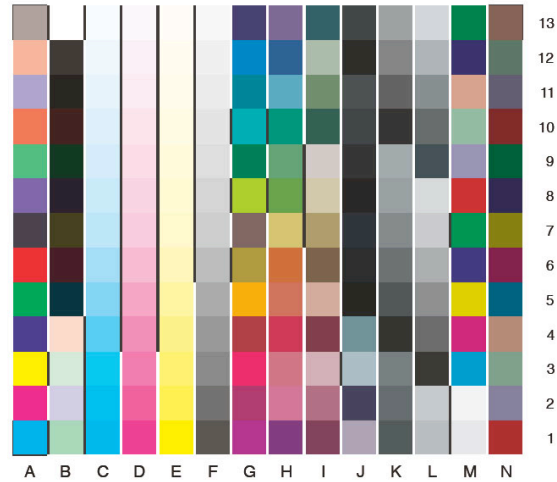


Figure 2. IT8.7/3 (basic) block

The second color chart is a collection of 320 color patches from 20 pictorial color images (Figure 3). The creation of the image-based chart is by sampling 16 colors of interest and their derivatives from each of the 20 pictorial color reference images (PCRI). In other words, the PCRI chart is image-based while the IT8.7/3 chart is colorant-based (Chung, 2006). In doing so, the PCRI images and the PCRI chart provide both a pictorial component and a synthetic component in the subjective and objective color agreement analysis.

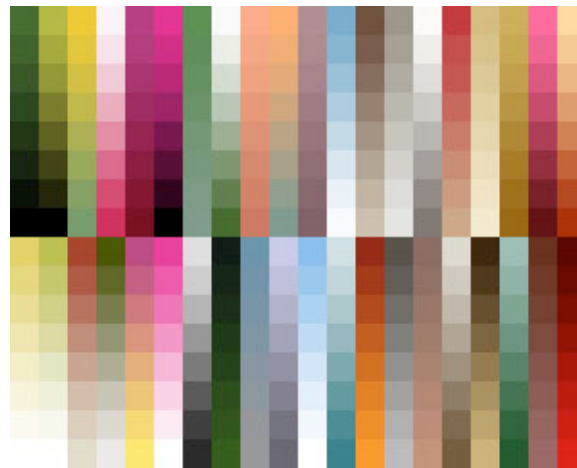


Figure 3. PCRI chart

In terms of data analysis, we compute color differences between the print and each of the proofs. The result is a distribution of ΔE_{ab} . We express the

ΔE distribution as a cumulative relative frequency or CRF (Chung, 2001). The location of the CRF curve is the prediction of the pictorial color image match between the print reference and a proof.

Results & Discussion

Figure 4 shows a number of quantitative color differences between two dissimilar hardcopy devices, SM74 and the Epson, based on measurement from the IT8.7/3 color chart. Notice that the gray-colored CRF curve of the initial (or unadjusted) proof falls on the far right. As different color image adjustments are applied, the CRF curves move to the left. By drawing a horizontal line at 50% tile, the intersection with various CRF curves is a prediction of the color image match from best to worst. In this instance, the IT8.7/3 color chart-based prediction, from best to worst, is D_PCS (purple), E_DLP (orange), A_Gradation (red), C_TrGb (green), and B_Chroma (cyan) or DEACB. The prediction, based on the IT8.7/3 (basic) chart, is different than the visual comparison results, i.e., EDCAB.

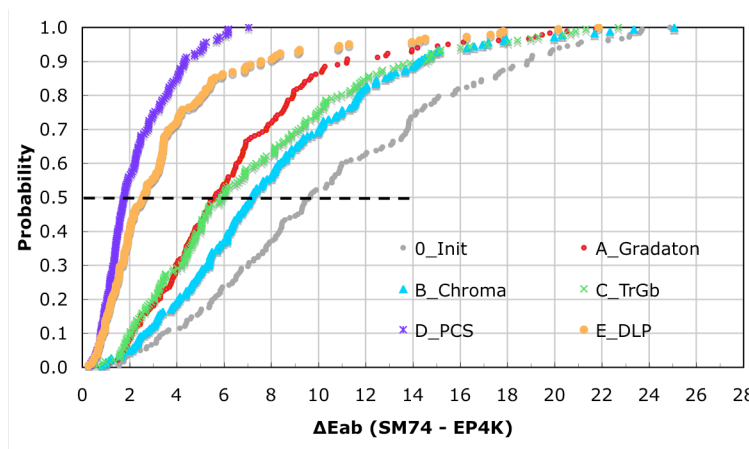


Figure 4. CRF of ΔE curves based on IT8.7/3 color chart

When designing the experiment, the inkjet printer controlled by a RIP was selected because it represents a sufficiently different colorant-substrate-printing condition than the offset. Thus, there was no surprise that the two color management methods outperformed the three calibration-based methods. We were surprised to see the closeness of the two CRF curves representing the gradation and the TrGb method. We suspect that there is a strong bias in colorant-based color patches, e.g., CMYK ramps in the IT8.7/3 basic chart, but not found in pictorial color image data.

Figure 5 shows the quantitative color difference between SM74 and the Epson based on measurement from the PCRI chart. Notice that there are

more separations among these CRF curves. By drawing a horizontal line at 50% tile, the image-based PCRI chart prediction between proof and print, from best to worst, is E_DLP, D_PCS, C_TrGb, A_Gradation, and B_Chroma or EDCAB. The prediction is the same as the visual comparison results.

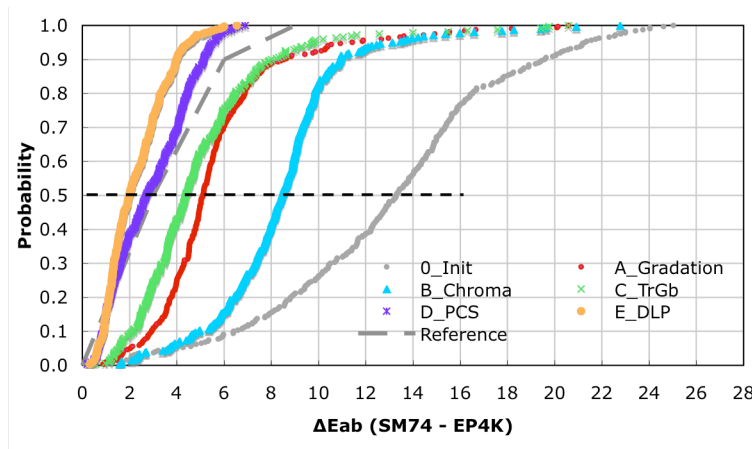


Figure 5. CRF of ΔE curves based on PCRI color chart

A number of observations of interest can be said about Figure 5: (1) the two ICC-based adjustments came out ahead. If we use the color image agreement threshold (represented by the dotted CRF curve), as mentioned in the previous study (Chung, 2001), both ICC-based color conversion methods produce good color agreement between proof and print; (2) the TrGb adjustment came in third indicating the limitation of the method in correcting color differences in primary and two-color overprint region of the color gamut; (3) the gradation adjustment came in fourth because there is no single color ramp in the image-based PCRI chart for it to take advantage of; and (4) the C^* adjustment did not account the lightness nor the hue difference between the proofs and the offset reference.

Conclusion & Further Research

Pictorial color image match between the press sheet and proofs, having large color gamut difference, has been studied subjectively and objectively. Color-managed proofs out performed proofs by calibration method. In addition, the correlation between subjective visual analysis and measurement-based quantitative analysis is a function of the color chart used. The image-based PCRI chart out performs the colorant-based IT8.7/3 chart.

A number of ideas surface as far as further research in this project. First, redundant patches in the PCRI chart may be reduced. Second, weighting

factors toward ΔE values for certain color patches, e.g., white point and neutrals, may be applied to better correlate with visual rankings. Third, more tests are necessary to find out how well the methodology performs over a wide range of pictorial color image reproduction. Finally, it would be useful to study two imaging devices that are closer in their native color behaviors. In this regard, we need to prevent process drifts and color measurement variation. Visual simulation and quantitative analysis of color difference with the use of ICC-enabled software will help preserve the effect of the color image adjustments.

Literature Cited

- Chung, Robert, Hsu, Fred and Liu, Wuhui
2007 "Achieving Color Agreement: Evaluating the Options," Proceedings of the 34th IARIGAI Research Conference, Advances in Color Reproduction, pp. 197-204.
- Chung, Robert
2006 "Pictorial Color Reference Images," Test Targets 6.0, RIT, pp. 42-45.
- Chung, Robert, and Shimamura, Yoshikazu,
2001 "Quantitative Analysis of Pictorial Color Image Difference," TAGA Proceedings, pp.381-398.