Process Color Profiling: Syncing a Digital Press with an Offset Press

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Abstract

For both printers and clients, accurate proofs are needed before going to press. The proof should predict what the job will look like on the press. Press proofing is an integral part of the printing process. It is important to customers that the colors on a digitally printed proof will match the colors printed on an offset press. The Larry Brink Printing Laboratory at Western Michigan University uses a Xerox Docucolor 12 for printing proofs for a Shinohara offset press. This project examines digital color proofing the offset press. In order to accomplish this, an ICC profile target was printed on multiple substrates on the offset press and the digital printer. These were measured to create output profiles for the two devices on the different substrates. These profiles were used to simulate the offset press with the digital printer. The proof was verified both numerically and visually. The experimental procedure, results and reasons for differences are discussed.

Introduction

Color reproduction needs to be consistent. An image should look the same on the computer monitor as it does when printed [1] However, many printers and presses have different characteristics and do not always output the same image [2-4] and different platforms treat displayed images differently [5]. This is because monitors are based on RGB values, while presses and printers are based on CMYK values. To make things more difficult, different printers and presses have varying interpretations of the CMYK values. That is because they have their own gamut, or range of reproducible colors [2,3]. The type of paper being printed on also changes how the image is reproduced [4,6-13].

The Shinohara Offset Press is a two-color sheet-fed press that uses the process colors to print full color images. Sometimes the press does not print the same image as shown on the computer monitor or proof. The Xerox DocuColor 12, which also uses process colors, has some discrepancies in the output of the color of the images as well.

Color management [4] can solve this problem by profiling the press and printer. If each device is profiled, their printed products will match one another, as well as what is on the monitor. Each type of paper will also yield the same color values.

Background

The quality and uniformity of color in printed products is very important in today's industry. Images must match and be consistent and reliable. Color management systems help carry out this concept and reduce or eliminate any color matching problems [4]. Color management is "the use of hardware, software and methodology to control and adjust color among different devices in an imaging system" [6].

Color management tries to make color more predictable. Translating color between devices using a device-independent profile connection space and standard profiles for each device makes color more predictable. A profile describes the characteristics of a device and then a color transformation is performed by a color management module (CMM) [4]. Using the profile and CMM will result in more accurate and consistent reproduction between devices, soft proofing, gamut checking and mapping and profile embedding. These features reduce the time and cost of reproducing color.

Color Basics

The basics of color theory must be discussed to understand how color management works. Color is a visual sensation that occurs when light reflected from an object is focused onto receptors in our eyes [4]. There are three factors that affect the color of an object—the light source, the object itself, and the human eye. A color management system must consider these three factors.

Color Theory

There are two main color theories that are the foundation of color reproduction in printing. The first is the additive color model, which is based on the primary colors of light—red, green and blue [4,6]. It involves transmitted light before it is reflected by a substrate. When red, green and blue are combined in varying intensities, they create a full spectrum of colors. When all three are mixed at equal intensities, they create white light. Computer monitors and television screens are based on the additive color model.

The subtractive color theory is the other main model [4,6]. It is based on light reflected from an object that has passed through pigments or dyes that absorb or subtract certain wavelengths, allowing others to be reflected. This reflected light is made by combining red, green and blue. When red and blue mix, they create magenta, when blue and green mix, they create cyan, and when red and green mix, they create yellow. Cyan, magenta and yellow are the resulting colors. When these three colors are mixed in equal intensities, they produce black. When the process is reversed, mixing cyan and magenta creates blue, magenta and yellow creates red, and yellow and cyan form green. The subtractive color model is used in all printers and presses.

Additive and subtractive colors are illustrated in Figure 1.

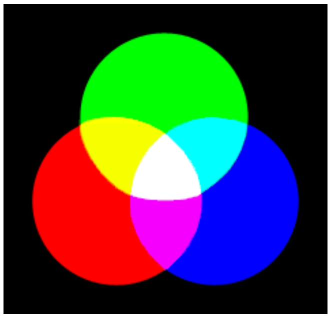

Figure 1. Additive Color Theory.

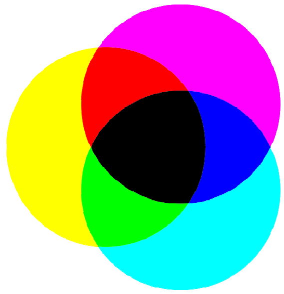

Figure 2. Subtractive Color Theory.

Color Theory

There are also color spaces that that help build the basis for color management by quantifying colors, or specifying colors by their positions in 3D space. These include XYZ, Yxy, Lab and LCH, which are specified by the International Commission on Illumination (CIE) [4]. They take into account the light source, object and human observer factors of the perception of light, so they are very closely correlated to how humans see color.

Color spaces are based on the three attributes of color: hue, saturation and lightness. Hue is the actual color (red, green, blue, yellow, etc.), saturation is the intensity or vividness, and lightness is how dark or light the color is. This can be represented in a 3D model, where the lightness is depicted on the vertical axis, saturation is shown on the horizontal axis and hue is depicted along the circumference of a cylinder.

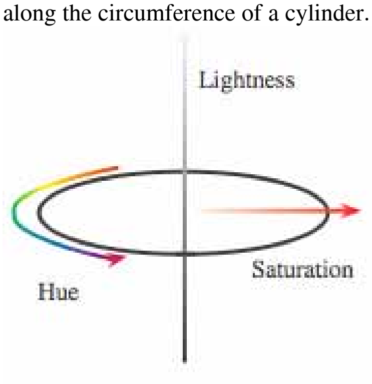

Figure 3. 3D Color Space Model.

CIE-LAB is one of the main color spaces focused on in this project and one of the most widely used [4]. L represents lightness, and a and b represent the hue and saturation. The values represent a color's position in the 3D sphere. This way, the distance between two colors can be quantified, which is important in color management. The difference between two colors is called ΔE [4]. A small difference in color will show a small numerical difference, and a large difference in color will show a large numerical difference.

The two color models mentioned earlier can also quantify color, by giving R, G and B or C, M, Y and K values. However, the difference between this quantification and that of a device independent color space, such as CIE LAB, is that RGB and CMYK are device-dependent. That means that they are specific to the device that they are used. These values will be different on each monitor or press, even if they are the same make and model. On the other hand, CIE-LAB is device independent and the colors will be the same on every device. LAB acts as an interpreter between RGB and CMYK. An RGB monitor will be converted into LAB values and then to CMYK values to be outputted.

RGB and CMYK also produce different gamuts, or color ranges. Monitors generally can produce a larger gamut than a printer, because it is RGB and the printer is CMYK. The gamuts also vary between each device. The gamut of a scanner depends on the technology and media used, monitors depend on the composition of the phosphor and printers depend on the inks and media. Therefore, printers may not be able to output all of the colors shown on the monitor and there will be a substitution of colors.

Profiles

ICC profiles are the key to color management and help perform the tasks of converting RGB to LAB to CMYK and translating monitor gamuts to printer gamuts. Their purpose is to maintain color consistency in images viewed, displayed or printed on different devices. This is accomplished by the use of a device independent Profile Connection Space. This space is where the profile is located, between the scanner and the monitor, the scanner and printer and the monitor and the printer. It connects each device, relating each one to a central color scale.

A proof is a process that simulates the results of a press on a printer, so the results can be seen before printing thousands of impressions. The profile made for the press is applied to the image and printed on the printer. It provides a preview of what it will look like on the press, in order to identify any possible problems. This saves time and money for printing companies and customers [4].

Project Objective

The goal of this project was to create a color management system allowing the Larry Brink Printing Laboratory to print color proofs on its Xerox Docucolor 12 digital printer that would match the color output of a Shinohara two-color offset press.

Equipment

The equipment used to complete this project included the following:

- Shinohara two-color offset press
- Xerox DocuColor 12 digital printer
- GretagMacbeth Spectrophotometer
- X-Rite 530 Densitometer
- Adobe Photoshop CS2 and Adobe InDesign CS2
- GretagMacbeth Measure Tool and ProfileMaker
- Linotronic 530 Imagesetter and Harlequin RIP
- Flint Ink Arrowstar Fast Setting Litho Process Inks

Methodology

The first step in building a color management system is to check the color consistency of the press being used. To do this, a 2002 Random CMYK ECI target was printed on the Shinohara on three substrate types; gloss, matte and offset. Ink density was measured with a densitometer during the press run to ensure the press was up to color.

The printed ECI targets were then measured with a GretagMacbeth SpectroScan and Measure Tool, and then used to create profiles in ProfileMaker. The profiles were applied to an InDesign document containing the same ECI Target, a Macbeth Color Checker and two four-color images by changing the CMYK "color settings" option to the appropriate profile and then converting the entire document. This process changed the Macbeth Color Checker's L*a*b* values to CMYK.

Once the document was appropriately profiled, it was output to film using a Harlequin RIP and Linotronic Imagesetter, plated and run again on the Shinohara. Density measurements were taken to ensure consistency between the two press runs and all variables were kept the same except during the second run when the plates were changed in accordance to the appropriate substrate.

After both press runs were complete, the profile was checked for accuracy and consistency by measuring the printed Color Checker with the X-Rite 530 and comparing it to the predicted print values. The predicted values were calculated by opening the Color Checker TIFF file in Adobe Photoshop and converting the file to the appropriate profile. The L*a*b* values were recorded from the Photoshop information palette and used to calculate a ΔE value,[4,14]

$$\Delta E = \sqrt{}(L_1\text{-}L_2)^2+(a_1\text{-}a_2)^2+(b_1\text{-}b_2)^2 \qquad (1)$$

Once the consistency of the press was measured and compensated for, the next step in the color management system was to create a profile for the Docucolor 12. This profile would be used to produce color accurate proofs to match the Shinohara.

The same ECI target was printed on the same three substrates using the Docucolor 12 with no color management. The targets were then measured with the SpectroScan and profiles were created using ProfileMaker with reference to the ECI target measurements from the Shinohara. The profiles were applied to an InDesign document containing the Macbeth Color Checker and two four-color images by changing the color settings and converting the document to the substrate specific profile.

The document was printed on the Docucolor 12 and the Color Checkers were measured and compared to the Photoshop values of the predicted print. An X-Rite 530 was used to measure the printed ColorCheckers and the predicted values were calculated in the same manner as those for the Shinohara, only the TIFF was converted to the Docucolor 12 profiles.

To calculate a single ΔE value for each substrate's Color Checker, each patch was measured three times and then averaged to find a ΔE for that patch. The ΔE values for each patch within one Color Checker were then averaged together to calculate a single value for the entire Color Checker.

Results

The first Delta E values calculated were between the printed Shinohara Color Checker and the Photoshop predicted print values. This ΔE number determined if profile built to create consistent prints on the Shinohara worked correctly. The ΔE values are shown in Table 1.

Table 1: Shinohara print VS Photoshop values

Substrate	Average ΔE
Gloss	10.23
Matte	11.31
Offset	13.14

An acceptable ΔE ranges between 2 – 6. This is a color variance too insignificant to be detectable by the naked eye. In this situation, the ΔE values are too high to be considered acceptable and show that the Shinohara press printed inconsistently. Reasons for this variance will be discussed later in this paper.

Next, the ΔE values were calculated between the printed Docucolor 12 Color Checker and the predicted print values from Photoshop. The Delta E values are shown in Table 2.

Table 3: Docucolor 12 print VS Photoshop values

Substrate	Average ΔE
Gloss	7.69
Matte	11.85
Offset	8.99

The values in Table 2 determine whether or not the profile created for the Docucolor 12 produced a consistent and expected print. Again, because these values are higher than the acceptable range of 2-6 ΔE, it is determined that the profile failed to create a consistent print on the Docucolor 12. Reasons for this inconsistency will be discussed later in this paper.

Finally, the Shinohara printed ColorChecker was compared to the Docucolor 12 printed ColorChecker to determine how accurately the digital printer was able to reproduce press color. The ΔE values are shown in Table 3.

Table 3: Shinohara print VS Docucolor 12 print

Substrate	Average ΔE
Gloss	11.35
Matte	12.22
Offset	18.17

The ΔE values in this comparison are once again too high to be considered acceptable. This shows that the prints made on the Docucolor 12 digital printer cannot be used as accurate color proofs for the Shinohara offset press using the profiles created in this project. Reasons for this color variance will be discussed later in this paper.

Conclusion

The profiles created in this project did not yield low enough color variance to be considered acceptable. This means that Larry Brink Printing Laboratory cannot use the created profiles to produce color accurate proofs on the DocuColor 12 digital printer for the Shinohara offset press.

This failure to accurately reproduce specific press and printer color gamuts could be a result of numerous variables. The inconsistency between the two press runs, and the failure to match the printed Shinohara ColorChecker values with the predicted Photoshop values could be due to an inaccurate profile.

As mentioned before, all press variables were kept the same between the two press runs to ensure consistency. But, during the first press run the cans of process color inks being used ran out. New cans of the same brand and type of ink were used on the second press run, but the cans came from a separate batch number than the first cans used.

Since the profile was built based on the first can of inks, using a new can of ink with varying pigmentation, could alter the printed results of the ColorChecker.

The reason for the inconsistency between the DocuColor 12 printed ColorChecker values and the predicted Photoshop values could be a result of the Fiery X12 RIP used to process files for printing. The RIP may automatically limit or expand the reproducible color gamut of the digital printer.

Because both the Shinohara and the DocuColor 12 did not print consistently, it would have been safe to assume that the printed ColorCheckers for each printer would have a high ΔE value. This is because the most important aspect of a color management system in consistency, which was not achieved during this project.

References

1. Veronika Chovancova-Lovell, Paul D. Fleming III, Ben Starr and Abhay Sharma, "Side by Side Soft Proofing with CRT and LCD Monitors", *TAGA J.*, **3**, 144, 2007
2. Alluri, Srinivasa R., "Generating ICC Output Profiles for Different Printing Devices: Application to a Shinohara Offset Press, Tektronix and HP Designjet", Masters Thesis, Western Michigan University, 2003.
3. Kailashnath Pohnerkar, "Generating ICC Output Profiles for Different Substrates: Application to a Shinohara Offset Press and Several Printers", Masters Thesis, Western Michigan University, 2003.
4. Sharma, Abhay, *Understanding Color Management,* Thomson Delmar Learning: New York: 2004.
5. Reem El Asaleh and Paul D. Fleming, "Cross Platforms Display Calibration and Profiling: (MacOs and Windows)", *Proceedings of the IS&T NIP23: International Conference on Digital Printing Technologies*, Anchorage, September 16-21, This Proceedings, 2007
6. "ColorSync Technology Brief." ColorSync. April 2001: pp 1-5, Scirus. Waldo Library, Kalamazoo, MI. 22 October 2006 <http://www.scirus.com>.
7. V. Chovancova-Lovell and P. D. Fleming III, "Color Gamut – New Tool in the Pressroom?", *TAPPI J*, 2007,in press.
8. Y. J. Wu, A. Pekarovicova, and P. D. Fleming, "How Paper Properties Influence Color Reproduction of Digital Proofs for Publication Gravure", *Proceedings of the 59th TAGA Annual Technical Conference*, Pittsburgh, PA, (2007).
9. Yu-Ju Wu, Paul D. Fleming III and Alexandra Pekarovicova, "Color Matching Capability of Digital Printers", *Proceedings of the IS&T NIP23: International Conference on Digital Printing Technologies*, Anchorage, September 16-21, This proceedings, 2007.
10. Steven D. Rice and Paul D. Fleming, "Lightfastness Properties of Different Digital Printers and Papers", *Proceedings of the IS&T NIP23: International Conference on Digital Printing Technologies*, Anchorage, September 16-21, This proceedings, 2007
11. Veronika Chovancova, Paul Howell, Paul D. Fleming III and Adam Rasmusson, "Color and Lightfastness of Different Epson Ink Jet Ink Sets", *J. Imaging Sci. Technol.*, 49 (6), November/December 2005, 652-659.
12. Veronika Chovancova-Lovell and Paul D. Fleming III, "Effect of Optical Brightening Agents and UV Protective Coating on Print Stability of Fine Art Substrates for Ink Jet", *Proceedings of the IS&T NIP22: International Conference on Digital Printing Technologies*, Denver, September 17-22, 227-230, 2006.
13. Lokendra Pal, Sachin Agate and Paul D. Fleming, "Effects of Paper Manufacturing Factors on Inkjet Print Quality and Lightfastness", , *Proceedings of the IS&T NIP23: International Conference on Digital Printing Technologies*, Anchorage, September 16-21, This proceedings, 2007.
14. CIE, Recommendations on Uniform Color Spaces, Color-Difference Equations, Psychometric Color Terms, Supplement No. 2 of CIE Publ. No. 15 (E-1.3.1) 1971, (Bureau Central de la CIE, Paris, 1978).
7\. Wilson, Daniel G., *Lithography Primer.* 2nd Ed. GATFPress: Pittsburgh, 1997.

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