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By Haji Naik Dharavath, Ph.D. and Swamy C. Basim, Ph.D.
Central Connecticut State University

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Color Quality Comparison of Electrophotographic vs. Inkjet Printing Processes In a Color Managed Digital Printing Workflow

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Introduction

Advancements in the computing, networking and digital printing technologies enable the digital print media to become a powerful multi-channel marketing and communications tool. Due to these changes, there is an increased demand for an educated, skilled and technically competent workforce. These changes have resulted in both opportunities and challenges and have created a need for an educated/skilled and competent workforce who understand the entire graphics and print media process and possess the skills necessary to manage print and non-print operations. In a quest to empower students to better understand the colorimetric attributes of color, this work examined the industry standard printing process and quality management practices similar to those a student would encounter upon entering into the industry. Hence, for a student to consistently deliver a quality print, managing and controlling color from the input device to a multicolor output device is a major concern for the graphics and imaging educator.

Analyzing the color image by examining its quantitative attributes eliminates the *subjective judgment on color quality evaluation of printed colors or colors in nature*. Advancements in science and engineering, however, have allowed print and graphic professionals to apply scientific research methods across prepress, pressroom, and quality control. Applying these methods heightens the importance of proper print production workflow. Workflow is represented through schematic illustrations of activities that reflect the systematic organization of analog and digital devices used during the print and image production process. A print ready e-file (.PDF or PostScript) is likely to be manipulated and later printed by an array of output digital devices *[computer-to-plate (CTP), digital printers and printing presses]*. Given each family of devices tends to create and produce color differently, the challenge is to manage color consistency across the entire workflow. Analysis of color image quality in the print process requires a Color Management System (CMS) to assist the color producer (press operator or the designer) in delivering accurate output colors regardless of device color capacities with the use of proper color management techniques. Color Management Workflow (CMW) or CMS uses a set of hardware tools and software applications at the output device front-end platform, working together to create accurate color between various devices: input, display, and output (See Figure 1).

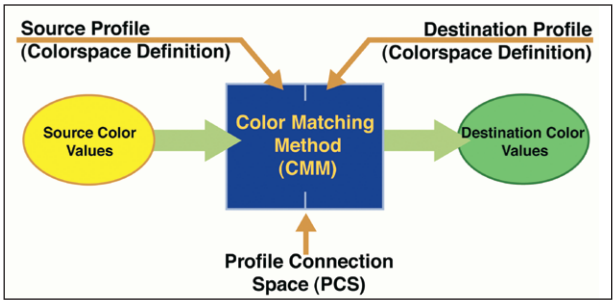

Figure 1: Schematic of PCS of CMS (Courtesy of Adobe Systems, Inc.)

Electrophotographic vs. Inkjet printing

A continuous-tone color image is composed of a full spectrum of shades and color, from near white to dense black. The method by which continuous-tone photographic images are transformed to a printable image is called halftoning. In this method, varying percentages of the printed sheet are covered with tiny dots called halftone dots or a halftone to represent the varying tones in the image. The ink (dry or liquid toner) printed by each dot, of course, has the same density. At normal viewing distance, the dots of the printed image create an optical illusion of a continuous tone image. A simple digital image could be a binary picture, [h(x, y)], with each point being either completely black or completely white (Pnueli & Bruckstein, 1996). Digital print technologies can be described as methods that do not use image carriers such as printing plates. Traditional printing methods such as offset lithography and flexography use different types of plates, while gravure uses an engraved cylinder to transfer the image, and screen printing uses stencils applied to framed mesh material.

Digital printing methods differ in that they usually do not have a direct physical impact on the substrate. I*nkjet printing* utilizes different methods of transferring liquid ink droplets to a substrate to create an image. Another digital printing technology known as color-electrophotography, or laser printing, is commonly used and employs charged toner particles that transfer electrostatically to the substrate and create an image that is fused to the surface. Laser and ink-jet printing generate the majority of digitally printed materials in the industry. Digital printing technologies today have reached a level of quality that is comparable to traditional printing methods. In studies of print quality using process color ink systems, there are a number of variables, such as dot gain, that may cause tonal variations, and can have negative influences on the accuracy of color reproduction. Measuring and recording certain color print attributes may enable the technologist to make controlled adjustments and then check these variables to see if positive changes can be affected and maintained.

Chroma, Delta E, and Hue (DE, C* and H*)

The L* c* h* color space uses the same coordinates as the L* a* b* color space, but it uses cylindrical coordinates instead of rectangular coordinates. In this color space, L* indicates lightness and is the same as the L* of the L* a* b* color space, C* is chroma, and h* is the hue angle. The value of chroma C* is 0 at the center and increases according to the distance from the center (See Figure 2). Hue angle h is defined as starting at the +a* axis and is expressed in degrees; 0° would be +a* (red), 90° would be +b* (yellow), 180° would be –a* (green), and 270° would be b* (blue). Metric chroma C* and the Metric hue angle h* are defined by the following formulas (Morovic, J., Green, P., & MacDonald, L. (2002):

Metric chroma $C^* = \sqrt{(a^*)^2 + (b^*)^2}$

Metric hue angle: $h^*_{ab} = \tan^{-1} (b^*/a^*)$

where: a*, b* are chromaticity coordinates in L* a* b* color space.

Gray balance is the proper percentage of combinations of cyan, magenta, and yellow inks that produce neutral shades of gray. Hue shifts will occur when there is any imbalance of one of the components. The imbalance is due in large part to ink impurities. Gray balance is a significant factor in determining overall color gamut. Gray balance can be determined by careful evaluation of a full set of tint charts printed with process inks. Colorimetric methods are used to determine *if the hue of gray* is desirable in order to make sure that the black ink scale is neutral. Calculation of ΔH* or ΔC* (or C*) requires colorimetric data from the L* a* b* model.

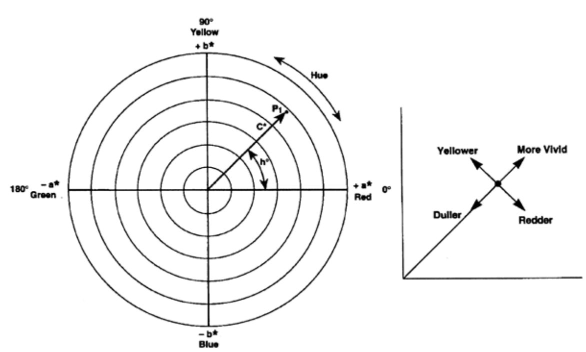

Figure 2: Schematic of L* c* h* coordinates.

Hue difference (ΔH^*) is calculated by the following formula (Morovic, J., Green, P., & MacDonald, L. (2002):

$$\Delta H^* = \sqrt{(\Delta E^*ab)^2 - (\Delta L^*)^2 - (\Delta C^*)^2}$$
$$= \sqrt{(\Delta a^*)^2 + (\Delta b^*)^2 - (\Delta C^*)^2}$$

CIE Color Difference (ΔE)

Assessment of color is more than a numeric expression. Usually it's an assessment of the difference in the color sensation (delta) from a known standard. In CIELAB color model, two colors can be compared and differentiated. The expression for these color differences is expressed as DE (Delta E or Difference in Color Sensation). The following equation is used to calculate the ΔE (ANSI/CGATS.5-2003, p.29):

$$\Delta E = \sqrt{(L^*_1 - L^*_2)^2 + (a^*_1 - a^*_2)^2 + (b^*_1 - b^*_2)^2}$$

where: 1 = Color 1 and 2 = Color 2

Purpose Of The Research

The experiment was conducted in a color managed workflow (CMW). The purpose of this experimental study is to determine the differences that exist among the printed primary colors hue (ΔH) deviation [Cyan, Magenta, Yellow, and Black (CMYK)], *overall average* (ΔE) *color* (CMYKRGB) deviation and *gray hue* (overlap of CMY) deviation (ΔH) of the two printing processes, namely: ***Color Electrophotographic and Inkjet*** *(groups, K = 2)* when compared with reference colorimetry. Reference colorimetric values are the threshold deviations (acceptable color deviations) as outlined in the ISO12647-7 standards. To accomplish this, the following guiding objectives have been established:

1. Determine the deviation in the color hue of CMYK (ΔH) *between the two printing processes* by comparing the printed colorimetry against the reference colorimetry.
2. Determine the deviation in color printing average/overall (CMYK+RGB) ΔE *between the two printing processes* by comparing the printed colorimetry against the reference colorimetry.
3. Determine the deviation in the color printing attribute of Gray ΔH (CMY overlap) *between the two printing processes* by comparing the printed colorimetry against the reference colorimetry.

Research Methodolgy

The experiment was conducted in a color managed digital printing workflow (CMDPW) to determine the differences that exist in the color quality of electrophotographic vs. inkjet printing, based on the colorimetric and statistical evaluation among two different types of printing processes. Each printing process used in the experiment was considered as a group, noted by letter "K" *(K = 2)*. This study was focused on the measurement of color prints, printed on the same type of substrate (80 LBS. gloss coated paper) by using a color electrophotographic (color laser) printer and an inkjet printer. The digital color printers used in this experiment are Konica-Minolta (KM) C6000bizHub color printer (or digital press) and EPSON StylusPro 7990 (Spectro-Proofer) Inkjet printer. KM C6000 uses a Creo IC-307 raster image process (RIP) server (front-end system) based workflow application and the EPSON printer utilized the CGS-ORIS Color Tuner workflow application. These workflow applications enable the printer (or designer) to emulate/simulate *(See Figure 3)* the device to print as per the ISO 12647-7 digital printing production standards. ISO 12647-7 device color characterization data set was used as a reference colorimetry. Industry standard brand 80 LBS gloss-coated digital color printing paper was used for printing on both the printers. Twenty-five samples for

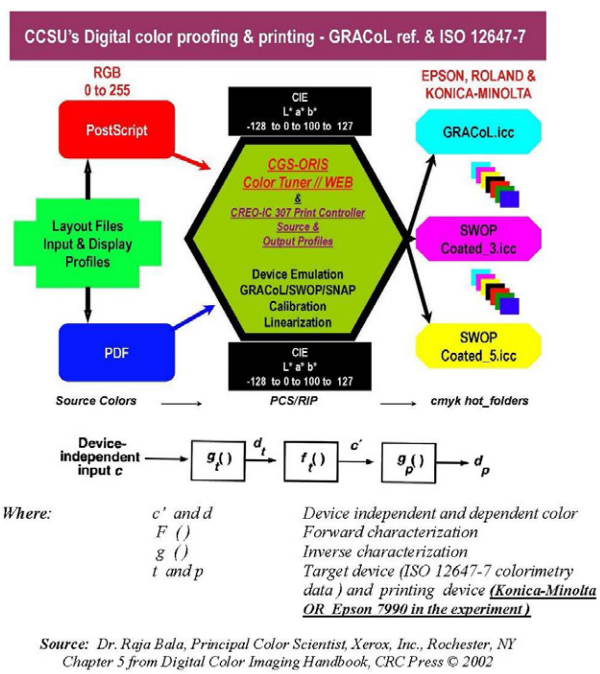

Figure 3: Digital Color Proof/Print Workflow

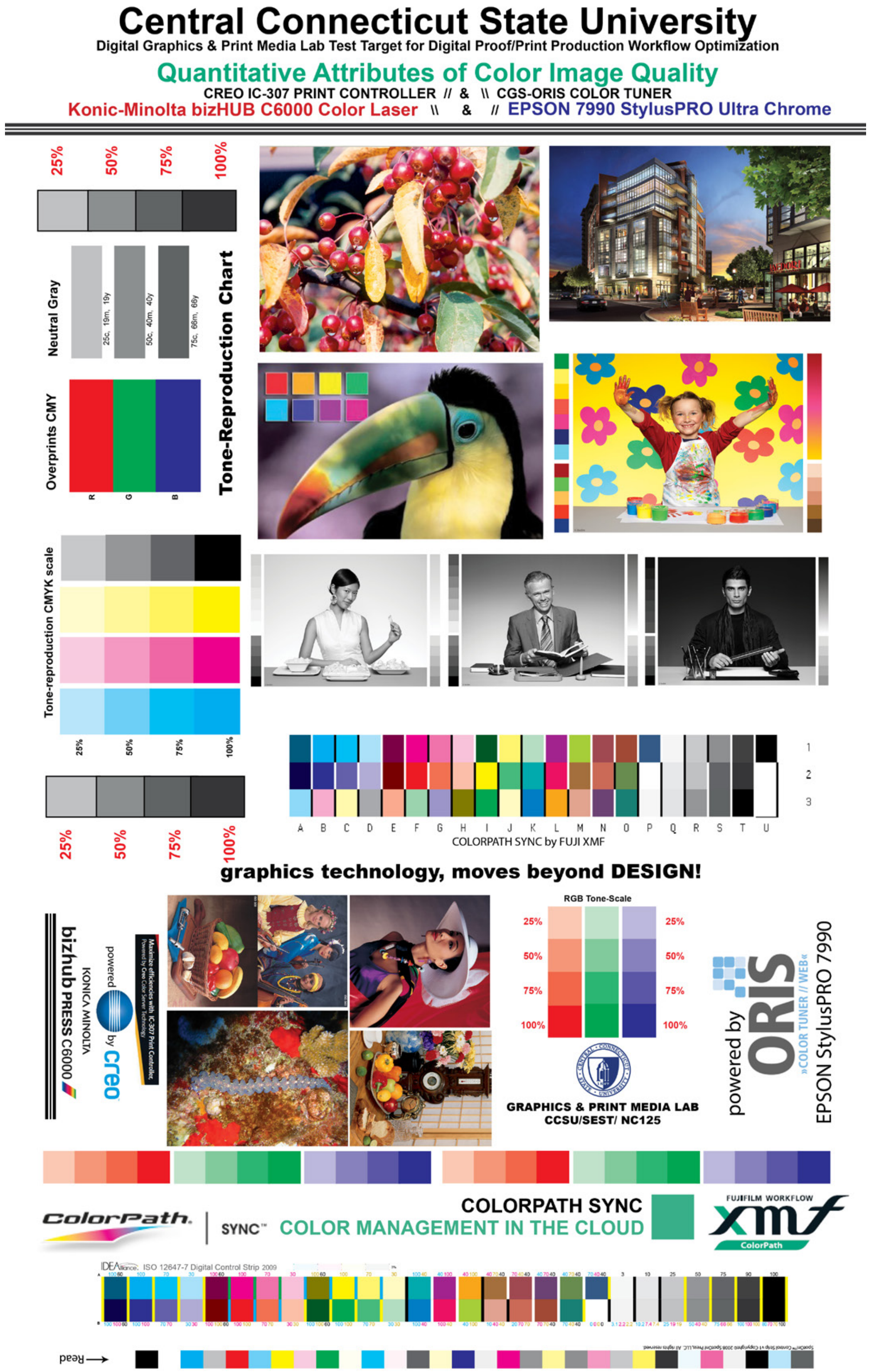

Figure 4: Test Image

each group were printed, noted by letter "n" (n = 25). For the two groups (K = 2), a total of 50 samples were printed, noted by letter "N" *(N = 50; K = 2)*. One-page custom test image (CCSU Test Image) of 12" x 18" size was created and used for proofing and printing *(see Figure 4)* in the experiment.

The test target (see Figure 4) contained the following elements: an ISO standard and generic images for subjective evaluation of color, an ISO 12647-7 Control Strip, Fujifilm's COLOR PATH Sync strip, etc. Upon printing, the data was collected *(from the printed samples or from the control strips)* by using multiple types of International Color Consortium (ICC) standard based color management applications (software) and instruments/devices *(Spectro-photometer & Densitomter)*. Colorimetric, densitometric, spectrophotometric and statistical computations were performed to determine the printing colors (solid CMYK), gray color (overlap of C = 50%, M = 40%, and Y = 40%) *"hue variation"* (ΔH), and *"average overall color deviation"* (ΔE) between the two (K = 2) types of printing processes.

Data Analysis

No random sampling technique was employed to select the sample size for analysis. Descriptive statistical methods were used to analyze the collected data. Color hue differences (ΔH), gray hue (ΔH), and average color deviations (ΔE) were compared to examine the noticeable color hue differences that exist among the printed samples of the two printing processes when compared with reference colorimetric deviations. Reference colorimetry is the threshold deviations as outlines in the ISO12647-7 standards (See Table 1). As stated in the previous section, the digital color prints (or proofs) were printed in a CMW. Colorimetric data was collected from the printed samples of each printing processes by using the *Fujifilm's ColorPath Verified* against the ISO12647-7 reference colorimetric data *(see Table 1)* to determine/compare the colorimetric deviations for Printing Colors Delta H (ΔH), Gray ΔH (CMY overlap), and average color deviations (ΔE). Colorimetric values of these attributes were mapped (bar chart) for visual comparison *(See Figure 5)* and tabulated in *Table 1*. Subjective judgment on color difference was not used in this study. The subjective judgment of color difference could differ from person to person. For example, people see colors in an image not by isolating one or two colors at a time (Goodhard & Wilhelm, 2003), but by mentally processing contextual relationships between colors where the changes in lightness (value), hue, and chroma (saturation) contribute independently to the visual detection of spatial patterns in the image (Goodhard & Wilhelm, 2003). Instruments, such as colorimeters and spectrophotometers, could eliminate the subjective errors of color evaluation perceived by human beings.

Table 1: Colorimetric Deviations: Reference VS. Printed Colors

Color	ISO 12647-7	Inkjet	Color Laser
Attributes	Colorimetric Reference Threshold Deviations		
ΔE Average	3.00	2.13	5.56
ΔH Primaries	2.50	3.09	1.61
ΔH Gray	1.50	0.52	1.04

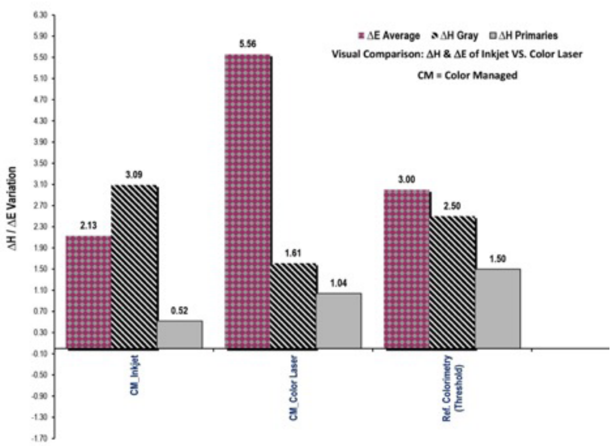

Figure 5: Visual Comparison of Color Deviations (Inkjet vs. Color Laser)

Summary

This experiment demonstrated the use of CMW to determine the influence of ICC color profiles for acceptable digital color output. The findings of this study represent specific printing or testing conditions. The images, printer, instrument, software, and paper that were utilized are important factors to consider when evaluating the results. The findings of the study cannot be generalized to other CMW. However, other graphic arts educators, industry professionals, and researchers may find this study meaningful and useful. For example, educators can implement similar models or this method to teach a color management module. The colorimetric data of this experiment led to the conclusion that the selection of printers, substrates, software, and instruments are very important in a CMW in order to output accurate colors of choice for a desired use/purpose. Derived colorimetric data and major findings (data and experience of the experiment) revealed that there were noticeable differences in the color reproduction between the two printing processes (See Table 1 and Figure 5).

References

Bruckstein, A.M. & Pnueli, Y. (1996). Gridless Halftoning: A Reincarnation of the Old Method. Journal of Graphical Models and Image Processing, 58(1), 38–64.

Committee for Graphic Arts Technologies Standards (CGATS). (2003). Graphic technology –spectral measurement and colorimetric computation for graphic arts image. (ANSI/CGATS.5-2003). Reston, VA: NPES, The Association for Suppliers of Printing and Publishing Technologies.

Goodhard, M. M., & Wilhelm, H. (2003). A new test method based on CIELAB colorimetry for Evaluating the permanence of pictorial images. Retrieved from http://www.wilhelm-research.com/. Grinnell, IA.

Morovic, J., Green, P., & MacDonald, L. (2002). Color engineering (pp. 297-314). New York, NY: John: Wiley & Sons.

Raja B. (2002). Digital Color Imaging Handbook (pp 372–373). New York, NY: CRC Press.

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- » Screen captures should be as large as possible.
- » Photos should be about 300 ppi to span one column (3-inches) or 2 columns (6.5-inches).
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