Dependence of Color Reproduction on Graphics Software and Digital Printing Processes

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Abstract

In the modern era of printing, controlled color reproduction plays a vital role in reflecting the capabilities of various software and hardware elements used during the printing process, so as to achieve the set target in terms of color. This is crucial for matching proof to press (and press to proof) and for accurate short run digital production. This study compares the color reproduction variations observed while printing a color managed test target with respect various digital printing mechanisms (electrophotography, ink-jet and dye sublimation) as well as effects on color reproduction of test targets by generating the document using different graphics software, such as Adobe Photoshop, Adobe InDesign and QuarkXPress.

As this study reflects the findings in color variations that incurred in color reproduction, using different page layout software while using proper color management procedures, it also reveals some standard procedures that can be accounted for to achieve better color reproduction and maintain repeatability of results.

Introduction

Color management (Sharma, 2004; Fleming and Sharma, 2002) allows a user to obtain controlled reproduction on various output devices, while implementing proper color management tools. While using a printer as an output device, it is

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very important to, during the printing process, use a suitable ICC profile (Fleming and Sharma, 2002; Swen et al., 1998) specifically created as per substrate-printer chemistry so as to obtain color accurate (Norberg and Anderson, 2003) printed images.

In current printing scenarios, color management plays an important role in color reproduction, being a system that supports color information exchange, color-matching, input/output profile management and device calibration. As color input, display and output devices, such as printers with different printing mechanisms proliferated, the need for color management has increased with the increase in use of color in media, packaging and printing industries. Color is the medium to represent various feelings and sensations in pictures, advertisements, etc. During the past few decades, input/output device manufacturing companies and commercial printers have laid a lot of emphasis on proper color reproduction and hence have been investing a lot of money and time in conducting research in this sector. Today, due to technological advancements, various color management tools are available for printers such as various color measuring and comparing instruments, profiling software for creating ICC profiles for various input/output devices, such as scanners, displays, printers, digital presses, etc.

As per everyday changing requirements of graphic developers, there are various page layout and graphic software systems used in digital printing processes. Due to day-by-day increasing demand of high quality and more precise color printing, it is also needed to select the page layout software to be used during the printing process as per its color handling capabilities, while implementing proper color management tools (King, 2002) and procedures. Therefore, the need of testing different page layout software on grounds of controlled color reproduction capabilities is justified. This study deals with comparing these color reproduction capabilities on various substrates and printers, while using the most widely used page layout software.

Experimental Procedure

1. Created ICC printer profiles for HP LaserJet CP 3505 color laser printer and Epson Stylus Pro 2200 ink-jet printer on all three paper samples used, i.e., Hammermill Color Copy Paper, Boise Multipurpose Printing Paper and Great White Color Copy Paper. In addition, created an ICC printer profile for a Mitsubishi CP3020A Dye Sublimation printer on the Mitsubishi paper its printer driver. For creating profiles for the HP printer, ECI2002CMYKi1_iO test-charts were printed on all three substrate samples from Photoshop CS5, InDesignCS5 and QuarkXPress 8 software. For creating profiles for the Epson printer, the ECI2002CMYKi1_iO test-charts were printed on the 3 given paper

substrate samples by converting the test-chart to PDF format using Photoshop CS5, InDesignCS5 and QuarkXPress 8 software and thereafter printing the PDF document using ORIS Color Tuner RIP software. After printing test-charts, Lab values of the color patches were measured using an X-Rite Eye-one iO scanning spectrophotometer and hence creating profiles using Profilemaker 5.0 software. The gamut values for all the above stated software-printer-substrate combinations were calculated using Colorthink Pro 3.0 software. For creating the profile for the Mitsubishi printer, a TC9.18 RGB i1_iO test chart was printed on the Mitsubishi paper from Photoshop CS5.

2. Created a Photoshop CS5 CMYK, an InDesignCS5 CMYK and a QuarkXPress 8 document comprising 10 patches of black with decreasing dot % from 100 to 10%, two sets of CMYK solid patches and Macbeth color checker chart for printing on the HP and Epson printers.

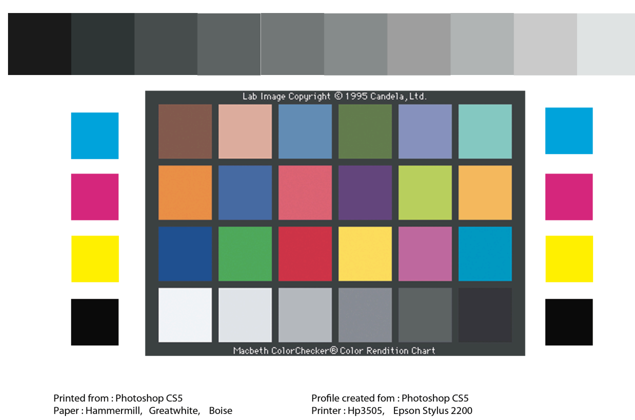


Figure 1. *CMYK test document created using PhotoshopCS5 software.*

3. The CMYK test documents created using PhotoshopCS5, InDesignCS5 and QuarkXPress 8 software were saved in multiple files and further converted to ICC profiles created by printing ECI2002 test-charts fromPhotoshopCS5, InDesignCS5 and QuarkXPress 8 software for all 3 substrate combinations for the HP printer. Thereafter, these CMYK documents were printed on the 3 selected substrates using the HP printer.

4. The CMYK test documents created using PhotoshopCS5, InDesignCS5 and QuarkXPress 8 software were saved in multiple files and further

converted to ICC profiles created by printing ECI2002 test-charts using PhotoshopCS5, InDesignCS5 and QuarkXPress 8 software for all 3 substrate combinations for the Epson printer. Thereafter, these CMYK documents files with embedded required ICC profiles were converted to PDF format and further printed on the 3 substrates using the Epson 2200 printer and ORIS Color Tuner (CGS) RIP software.

5. After printing all test documents, L*a*b* values for all 24 color patches of the Macbeth color checker chart were measured using the X-Rite Eye-One iO. These values were used to calculate the difference (ΔE) from the soft proof (Photoshop Info Palette) values to each of the printed target color values.

6. Various surface and optical properties such as surface macro-roughness, porosity, brightness and color values (CIELAB) for aforesaid 3 selected paper samples were measured using Parker Print Surf, Technidyne Brightimeter and the X-Rite Eye-One IO instruments. Permeability coefficients (Pal, et al., 2006) of the substrates were hence determined by calculations involving the application of Darcy's law using measured PPS porosity and caliper values.

7. ANOVA test was conducted for color gamut and ΔE values using MINITAB 16 statistical software.

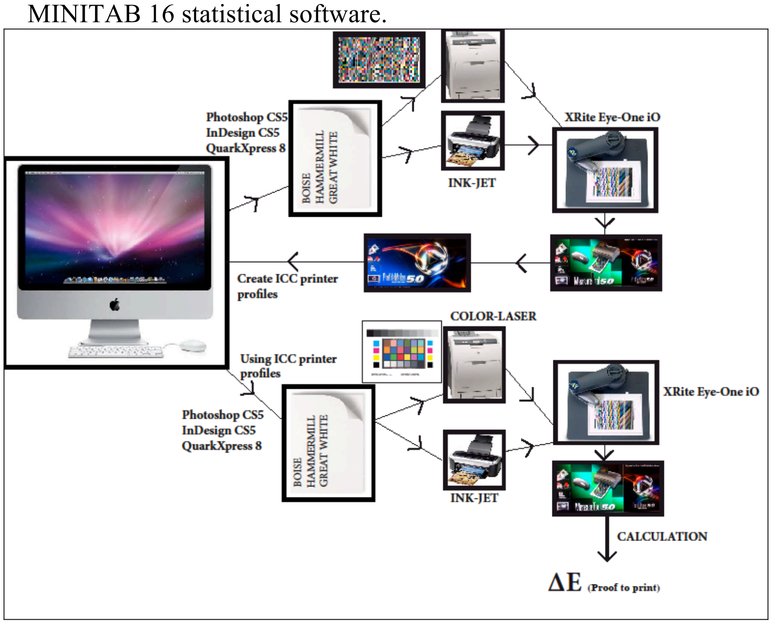


Figure 2. *Schematic of experimental procedure followed for calculating ΔE values.*

Results & Discussion

Table 1 refers to results obtained from ANOVA for gamut volumes obtained while printing the ECI2002CMYKi1_iO test-chart using different available software-printer-substrate combinations. The term "profiling software" refers to the software (Photoshop/InDesign/Quark) used to print the ECI2002 test-charts so as to create ICC profiles. The results show that the dependency of gamut volume being significant only on substrate chosen for printing considering a 95% confidence limits. The other factors such as profiling software and printer used shows significance of dependency up to 63% and 78% confidence limits respectively.

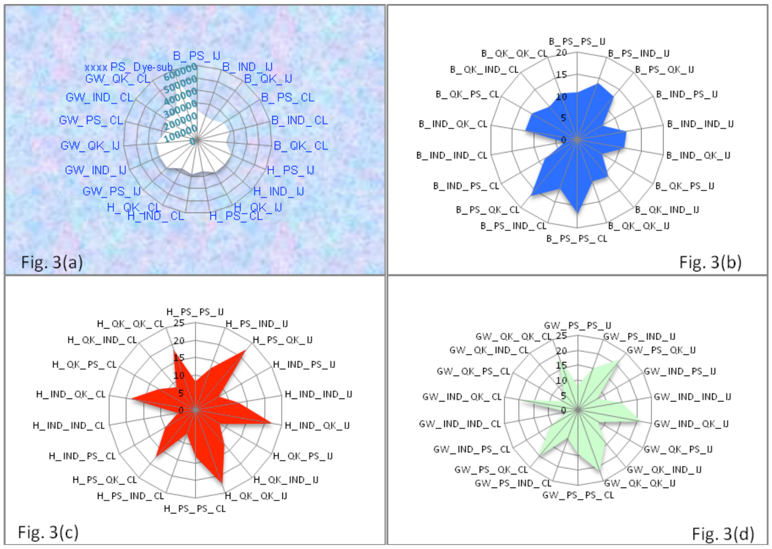
Analysis of Variance for Gamut Volume, Using Adjusted SS for Tests

Source	***DF***	***Seq SS***	***Adj SS***	***Adj MS***	***F***	***P***
Substrate	2	17865195771	17865195771	8932597886	12.57	0.001
Profiling Software	2	580698980	580698980	290349490	0.41	0.673
Printer	1	1192200727	1192200727	1192200727	1.68	0.220
Error	12	8526518748	8526518748	710543229		
Total	17	28164614227				

S = 26656.0 R-Sq = 69.73% R-Sq(adj) = 57.11%

Table 1. *ANOVA Results for Gamut Volume.*

Figure 3(a) corresponds to color gamut volume plot for various substrate-profiling software-printer combinations and the abbreviations used in the radar plot are defined in Appendix 1. Figures 3(b)–3(d) show the radar plots for ΔE values obtained while printing the CMYK test target including Macbeth Color Checker chart, while using various profiling software-printing software-printer combinations on Boise, Hammermill and Great White papers. The term "printing software" refers to the software (Photoshop/InDesign/Quark) from which the CMYK test target including the Macbeth color checker chart has been printed on specified substrate-printer combination while converting the test target to required ICC profile created using the "profiling software." These radar plots show the significant effect of using different combinations of profiling-printing software and substrates onto color difference of printed image observed by determining ΔE values of printed target-soft proof.



* The notations in Figure 3(a) denote substrate_profiling software_printer, whereas in Figures 3(b)–(d) they denote substrate_profiling software_printing software_printer.

Figure 3. *Color gamut and ΔE value radar plots.*

Table 2 refers to results obtained from ANOVA for ΔE values determined while printing test target on different substrates and using various profiling software-printing software-printer combinations. The results reveal significant dependence of substrate, profiling software and printing software on color matching (ΔE values) at 94.3%, 93.6%, and 99% confidence limits respectively, whereas the printing process/printer used is significant up to 78% confidence limit only.

Analysis of Variance for Delta E, using Adjusted SS for Tests

Source	***DF***	***Seq SS***	***Adj SS***	***Adj MS***	***F***	***P***
Substrate	2	75.20	75.20	37.60	3.04	0.057
Profiling software	2	68.32	68.32	34.16	2.76	0.074
Printing software	2	741.64	741.64	370.82	30.00	0.000
Printing Process	1	19.14	19.14	19.14	1.55	0.220
Error	46	568.60	568.60	12.36		
Total	53	1472.89				

S = 3.51580 R-Sq = 61.40% R-Sq(adj) = 55.52%

Table 2. *ANOVA Results for ΔE values.*

Figure 4 and Table 3 refers to the dependence of ΔE values with surface roughness and permeability of substrates. The main effects plot as shown in Figure. 4 also denotes the dependence of ΔE values on different profiling-printing software combinations.

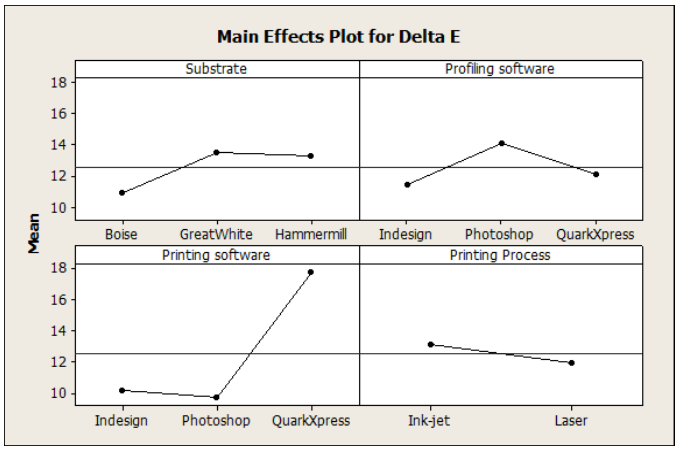


Figure 4. *Main Effects Plot for ΔE values obtained from ANOVA.*

Substrate	PPS Roughness (μm)	Permeability Coeff. (μm^2)	Brightness	L	a	b
Boise	5.48	0.005086188	92	91.2	1.2	–5.7
Hammermill	4.73	0.004260814	96	91.7	1.6	–7.8
Great White	3.78	0.002822069	92	92.2	2.3	–8.1

Table 3. *Substrate surface and optical properties measurement values.*

Conclusions

The experimental analysis shows significant dependence of color reproduction capabilities on page layout/printing software used. The gamut volumes and ΔE values obtained for specified substrate-printer combinations significantly depend more on chemico-physical properties of substrate, rather than mainly on substrate surface topographical properties, such as macro-roughness and permeability coefficient. Dye-sub printing provides very high color gamut as compared to ink-jet and laser printing using copy paper, which may be a result of special substrate requirement for dye-sublimation printing.

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Appendices

Appendix 1: Abbreviations used for graphical representation in radar plots.

Abbreviations used for Graphical Representation	
CL	Color Laser printer (HP CP 3505)
IJ	Ink-jet printer (Epson Stylus Pro 2200)
Dye-Sub	Dye Sublimation Printer (Mitsubishi CP3020DA)
PS	Adobe Photoshop CS5
IND	Adobe InDesign CS5
QK	QuarkXPress 8
B	Boise X-9 Premium Multipurpose paper
H	Hammermill Color Copy paper
GW	Great White Imaging paper
xxx	Mitsubishi Dye Sublimation Paper