Spot Color Reproduction with Digital Printing

Miro Suchy, Paul D. Fleming III and Abhay Sharma, Center for Ink and Printability, Department of Chemical Engineering, Paper Engineering and Imaging, Western Michigan University, Kalamazoo, MI, USA

Abstract

*Clear Color management with ICC profiles is used to investigate reproduction of Pantone Matching System colors for different digital printers. Three digital printers: XEROX Phaser 8200, FUJI PictroProof II and EPSON Stylus Photo 2200 were tested and their measured color gamuts were compared. The quality of reproduction is evaluated in terms of the usual ΔE in L*a*b* color space for selected PANTONE Matching System colors.*

Introduction

The advantages of conventional printing techniques, such as gravure, flexography or lithography, are usually fully realized when long print runs are required.[1] Large print quantities compensate for relatively long lead-times and high initiation costs (i.e. high cost of gravure presses), coupled with relatively high press set up times and make-ready.

The general trend in the printing industry leads towards offering greater flexibility in processing large varieties of substrates, inks and methods of print finishing. Run lengths are getting shorter and the greatest growth is expected in the market for small color work with fast turnaround time.

Recent developments in digital printing,[1] including modern digital-to-plate technology,[2] digital presses[3] and state-of-the-art laser printers,[1,3] have made it possible to produce small quantities of high-quality color products at affordable prices. Pre-press/setup costs are significantly lower than most plate printing methods. In addition, digital images can be produced in virtually any size in the range from a few inches to over sixteen feet in width.[4]

While the digital printing is not expected to completely replace the conventional printing techniques,[1] it can be used to help reduce their overall cost and shorten the time from receiving the order to actual printing. As an example, digital printing can be used for proofing, replacing conventional procedures (preparing cylinders and printing proof sample) for potential product verification. In addition, digital workflow within a properly controlled system can speed up the process of communication and quality verification between the print company and the customer.

The possibility of implementing digital proofing - printing simulation using a digital printer - is closely related to the recent developments in color management.[5] To mimic actual properties of, for example a gravure press, using a different printing process, different inks, materials and possibly devices at different location is quite a complex problem. However, properly color-managed workflow, where correlations between different printing devices are established via device profiles, and characteristics of material used are taken into account, makes this possible.

The overall objective of this investigation is to establish a digital proofing system for product gravure printing. In the first stage, different digital printers were tested and characterized by generating ICC profiles.[6] These profiles then can be used to compare the device gamuts - the defined color range a device can reproduce. In product gravure printing, specific color inks are generally used to meet the requirements of a customer. Therefore, the generated ICC profiles for each digital printer tested were used to investigate reproduction of PANTONE Matching System (now called Color Bridge[7]) colors for the different digital printers. Clear Color management with ICC profiles is used to investigate reproduction of Pantone Matching System colors for different digital printers. Three digital printers: XEROX Phaser 8200, FUJI PictroProof II and EPSON Stylus Photo 2200 were tested and their measured color gamuts were compared. The quality of reproduction is evaluated in terms of the usual ΔE in L*a*b* color space for selected PANTONE Matching System colors.

Experimental

Three digital printers: a XEROX Phaser 8200, a FUJI PictroProof II and an EPSON Stylus Photo 2200 were tested and compared. ICC profiles were generated for all the printers, each device profiled as a CMYK device. For each printer, manufacturer recommended paper was used for testing, the EPSON Stylus Photo 2200 printer was tested for two types of paper: matte and glossy coated.

ECI2002CMYK DTP41(Ltr) and ECI2002R CMYK charts were printed on each device without any color management or color adjustments. Printed charts were then measured with an X-Rite DTP41 spectrometer and GretagMacbeth SpectroScanT, both operated by GretagMacbeth Measure Tool 5.0 software. The measurement files were the used to generate profiles using GretagMacbeth ProfileMaker Pro 5.0.1. The profile settings were as folloes: Large profile size, Paper colored gray rendering intent, LOGO classic gamut mapping. Separation settings: GCR4 redefined with black start set to 0.

The gamuts of the tested devices were the compared using ColorThink 2.1.2 software. Finally, a color chart containing several of PANTONE Color Matching System colors was created. In Photoshop CS, using the ICC profiles of each units, the original chart was converted to these profiles, and the change in L*a*b* values after assigning the profiles were measured using the color histogram tool within Photoshop. The charts were then printed (using the corresponding printers) and the L*a*b* values for each color patch of the chart were measured using GretagMacbeth SpectroScanT. The difference in the values was expressed in form of ΔE.[8]

Results and Discussion

Gamut Comparison

ColorThink 2.0.1 software is designed, among other things, to compare gamuts of printing devices in 3D CIE L*a*b* color space. Based on preliminary results, the EPSON Stylus Photo 2200 printer was expected to have the largest gamut of the devices tested. The profiles were generated using Matte and Gloss coated papers.[9,10] The comparison of the gamuts is shown in Figure 1.

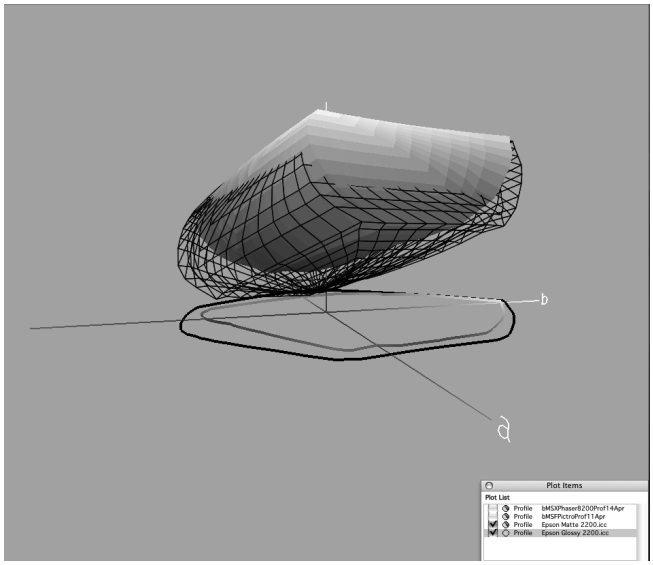

Figure 1. EPSON Stylus P2200 gamut for Matte and Gloss coated paper

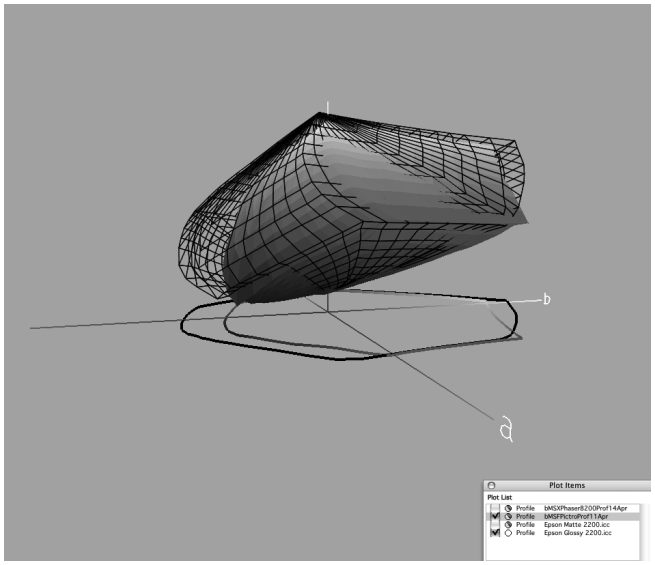

Figure 2. EPSON Stylus P2200 Gloss paper and FUJI PictroProof II gamut comparison

A larger gamut of the printer was measured for Gloss coated paper (black mesh). While the gamuts were similar in the green and yellow areas of the color space, significant differences were observed in blue and red regions. The EPSON Stylus Photo 2200 gamut was compared with the gamut of Fuji PictroProof II printer. The comparison is shown in Figure 2.

The gamut of FUJI PictroProof II printer was smaller compared to that of EPSON Stylus Photo 2200 (gloss paper). While the gamuts were similar in green/yellow and red regions, a small difference was observed in yellow/red region, and quite large difference was observed in blue and blue/red regions, EPSON Stylus Photo 2200 printer gamut having the larger gamut. The last device tested was XEROX Phaser 8200 printer. The gamut comparison with gamut of EPSON Stylus Photo 2200 printer is shown in Figure 3.

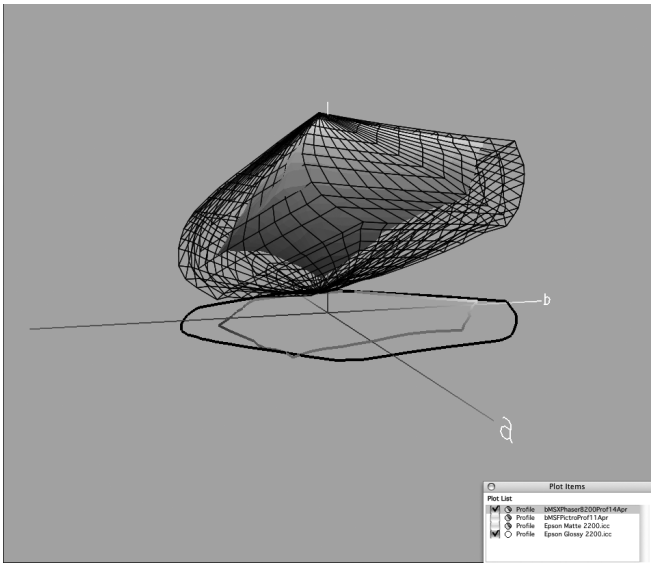

Figure 3. EPSON Stylus P2200 Gloss paper and XEROX Phaser 8200 gamut comparison.

Of the printers tested, the XEROX Phaser 8200 printer appears to have the smallest gamut. Except for yellow and green regions, the gamut is significantly smaller compared to the gamut of EPSON Stylus P2200 printer.

Based on these comparisons, of the printers tested the EPSON Stylus Photo 2200 has the largest gamut.

*PANTONE Matching System Color L*a*b* Comparison*

The quality of reproduction was evaluated in terms of the usual ΔE in L*a*b* color space[8] for selected PANTONE Matching System[7] colors. A color test chart was first built using 17 colors from PANTONE Matching System library (Pantone coated). The list of selected colors and original L*a*b* values is shown in Table 1. The L*a*b* values for the PMS colors were obtained from the Photoshop PMS Library.

With the exception of the blacks, the colors in the chart were of high saturation. The objective was to select challenging color targets and to evaluate the ability of the printers to reproduce them. It was expected that some of the colors would be out of gamut of the devices, contributing to the relatively high ΔE average values. The location of the colors in L*a*b* color space and is shown in Figure 4 (L*a* and L*b* projections). The gamut of EPSON Stylus Photo 2200 is included for reference.

Table 1: PANTONE Matching System Colors L*a*b* Values

PANTONE Color Name	PANTONE L*a*b*		
	L*	a*	b*
Process Yellow C	89	-4	103
Process Magenta C	45	78	2
Process Cyan C	57	-38	-46
Yellow C	89	-4	112
Yellow 012 C	87	2	114
Orange 021 C	63	63	95
Warm Red C	57	71	53
Red 032 C	54	74	41
Rubine Red C	44	78	8
Rhodamine Red C	52	79	-19
Purple C	46	68	-48
Violet C	24	54	-71
Blue 072 C	19	40	-79
Reflex Blue C	19	32	-74
Process Blue C	47	-33	-57
Green C	60	-78	2
Black C	18	2	6
Process Black C	9	0	0

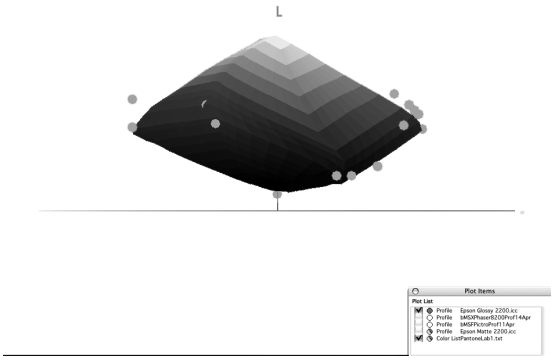

*Figure 4. Test-chart colors position in CIE L*a*b* color space vs. EPSON Stylus P2200 Gloss paper gamut*

The color chart was then open in Photoshop CS, and the image was converted to a selected printer profile. Once converted (in L*a*b* mode), the L*a*b* values were measured using color histogram for each color patch in the chart. These measured values are the values expected when the chart is actually printed on the device profile of which was applied to the chart in Photoshop.

The measured L*a*b* values for each printer and calculated ΔE for each color are shown in Table 2.

The comparison of calculated average ΔE values for each printer confirmed the largest gamut measured for EPSON Stylus Photo 2200 printer when printed on Gloss coated paper. The XEROX Phaser 8200 printer was also confirmed to have the smallest gamut.

Despite different shapes of color gamuts, the EPSON Stylus Photo 2200 (Matte) and FUJI PictroProof II printers measured similar average ΔE (21.0 and 21.2 respectively). The profile shape comparison is shown in Figure 5. The test-chart colors are also included for reference.

Table 2: ΔE (Photoshop vs. Original Values) Comparison of PANTONE Matching System Colors for Tested Printers

PANTONE Color Name	Xerox Phaser 8200	FUJI Pictro Proof II	Epson Stylus P2200 (Matt)	Epson Stylus P2200 (Gloss)
	ΔE	ΔE	ΔE	ΔE
Process Yellow C	19.0	11.0	3.2	4.6
Process MagentaC	33.6	4.8	13.0	6.8
Process Cyan C	20.9	11.3	6.9	1.1
Yellow C	30.4	19.6	12.4	14.0
Yellow 012 C	37.3	26.5	18.2	21.4
Orange 021 C	52.5	39.5	37.6	35.1
Warm Red C	30.5	20.3	20.4	17.6
Red 032 C	29.5	15.4	19.5	14.2
Rubine Red C	37.1	4.5	14.2	6.7
Rhodamine Red C	21.8	14.4	15.0	6.9
Purple C	28.7	33.2	31.8	17.3
Violet C	51.4	44.9	44.9	21.1
Blue 072 C	55.2	48.6	44.5	24.0
Reflex Blue C	45.6	38.7	35.5	12.0
Process Blue C	28.3	18.7	12.6	7.9
Green C	23.0	25.8	25.4	15.3
Black C	8.9	1.2	9.3	0.9
Process Black C	12.0	3.2	13.2	3.0
Average	**31.4**	**21.2**	**21.0**	**12.8**

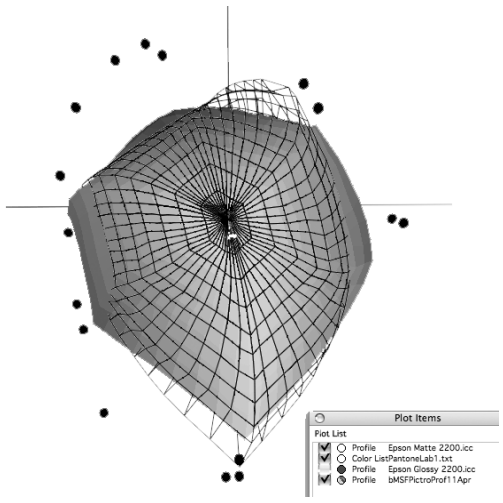

Figure 5. EPSON Stylus P2200 Matte paper and FUJI PictroProof II gamut shape comparison

This comparison is not truly representative of overall color gamuts. This applies only to the selected colors in the test chart. There are other methods/software that can be used to better quantify the gamut differences, and which will be used in later stages of this investigation. In addition, large calculated ΔE values for some of the colors are caused by out-of-gamut colors, which cannot be reproduced by the tested devices.

In the final part of this preliminary investigation, the chroma difference (ΔEab) was calculated for each color in the test chart and each printing device. The measurement and calculation is similar to that of ΔE, except the contribution of L* is neglected. This calculation helps to establish how close each device was able to create the desired color hue. The results are shown in Table 3.

The comparison of gamuts and PANTONE Matching System colors included in the test-chart is shown, projected in a* vs. b* plane is shown in Figure 6.

These projections clearly demonstrate that the majority of colors selected from PANTONE Matching System are outside of the gamuts of the tested printers. The EPSON Stylus Photo 2200 in combination with gloss coated paper demonstrated the largest gamut by quite a significant margin.

Table 3: ΔE_{ab} (Chroma Difference) Comparison of PANTONE Matching System Colors for Tested Printers

PANTONE Color Name	Xerox Phaser 8200	FUJI Pictro Proof II	Epson Stylus P2200 (Matt)	Epson Stylus P2200 (Gloss)
	ΔEab	**ΔE**ab	**ΔE**ab	**ΔE**ab
Process Yellow C	18.2	10.3	3.2	4.4
Process Magenta C	33.1	4.7	12.7	6.7
Process Cyan C	20.9	11.3	6.9	0.5
Yellow C	29.6	19.0	12.3	13.7
Yellow 012 C	36.4	25.8	18.0	20.9
Orange 021 C	52.3	39.3	37.5	34.8
Warm Red C	30.5	20.2	20.4	17.4
Red 032 C	29.5	15.3	19.5	14.0
Rubine Red C	36.5	4.5	14.0	6.6
Rhodamine Red C	21.7	14.4	14.9	6.8
Purple C	28.5	33.2	31.4	17.3
Violet C	48.7	43.1	41.9	20.5
Blue 072 C	51.6	46.1	41.1	22.2
Reflex Blue C	42.1	36.4	32.2	10.9
Process Blue C	28.0	18.6	11.8	5.9
Green C	22.9	25.7	25.4	15.1
Black C	1.9	1.1	5.2	0.3
Process Black C	1.0	2.5	1.2	0.7
Average	**29.6**	**20.6**	**19.4**	**12.2**

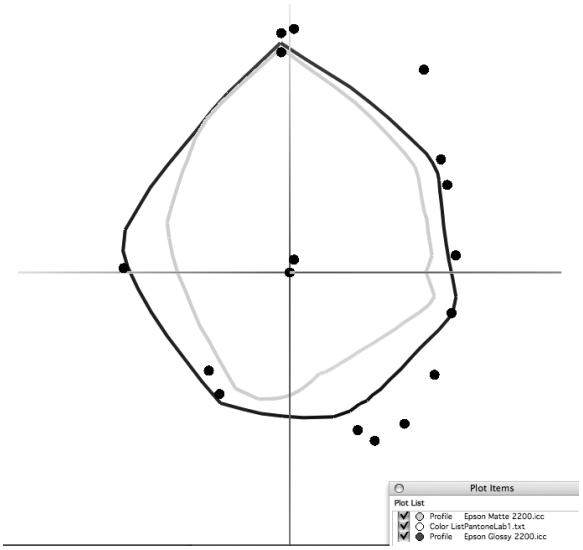

Figure 6. EPSON Stylus P2200 gamut for Matte and Gloss coated vs. test-chart colors.

*Photoshop Predicted and Actual Printed L*a*b* Values Comparison*

The accuracy of the generated profiles was evaluated by printing the color chart and measuring the actual L*a*b* values. The measured values were then compared with the Photoshop expected L*a*b* values, described in the previous section. The difference, expressed as ΔE, is a measure of profile quality.

The chart was first open in Photoshop CS, and using the ICC profiles of each unit, the chart was converted to a selected printer profile. The chart was then printed using corresponding printer and the L*a*b* values of each color patch was measured using GretagMacbeth SpectroScanT. The measured values were then compared with the original L*a*b* values of the chart, and with the values measured in Photoshop. Profile quality evaluation for each printer is shown in Table 4.

The first ΔE value indicates the difference between original and Photoshop measured L*a*b* values for each color of the chart. The second ΔE value is the difference between original and printed L*a*b* values, and the third value shows the difference between predicted and actual (printed) L*a*b* values.

The calculated difference in ΔE for Photoshop predicted and actual printed L*a*b* values was similar for all the printers tested, and the average values of ΔE were lower than 3 for all measured printers. The highest difference was measured for EPSON Stylus Photo 2200 printer and Gloss coated paper (2.9 ΔE).

Conclusions

The objective of this preliminary investigation was to compare color gamuts of several digital printers and to investigate possible reproduction of Pantone Matching System.

Table 4: ΔE Comparison of PANTONE Matching System Colors for Tested Printers

PANTONE Color Name	Xerox Phaser 8200	FUJI Pictro Proof II	EPSON Stylus P2200 (Matt)	EPSON Stylus P2200 (Gloss)
	ΔE	**ΔE**	**ΔE**	**ΔE**
Process Yellow C	19,18,1	11,9,2	3,3,1	5,5,1
Process Magenta C	34,33,1	5,5,2	13,12,4	7,5,6
Process Cyan C	21,20,2	11,10,2	7,6,1	1,1,2
Yellow C	30,30,0	20,19,1	12,14,1	14,15,2
Yellow 012 C	37,37,1	26,25,1	18,22,4	21,21,1
Orange 021 C	52,52,1	40,41,2	38,36,2	35,35,1
Warm Red C	30,29,3	20,19,3	20,20,1	18,18,1
Red 032 C	29,28,2	15,15,2	19,19,1	14,14,2
Rubine Red C	37,37,3	5,4,1	14,12,4	7,4,6
Rhodamine Red C	22,22,2	14,13,2	15,16,2	7,5,2
Purple C	29,29,1	33,34,2	32,31,2	17,15,2
Violet C	51,49,3	45,47,4	45,45,2	21,20,1
Blue 072 C	55,55,3	49,50,2	45,44,3	24,24,7
Reflex Blue C	46,44,3	39,40,2	36,34,3	12,12,3
Process Blue C	28,27,3	19,18,3	13,11,2	8,7,6
Green C	23,23,3	26,23,4	25,24,3	15,15,5
Black C	9,6,4	1,6,5	9,7,5	1,1,2
Process Black C	12,9,6	3,5,2	13,13,1	3,3,2
Average	**31,31,2**	**21,21,2**	**21,21,2**	**13,12,3**

Of the three digital printers tested, the EPSON Stylus Photo 2200 showed the largest gamut size. The color test chart consisting of 17 colors from PANTONE Matching System library was used to test the ability of the printers to reproduce the colors. Large ΔE values obtained for some of the colors indicate that these colors cannot be reproduced by some of the devices. The major conclusion of this investigation is the selection of EPSON Stylus Photo 2200 printer as the device, which will be used for further testing. The EPSON Stylus Photo 2200 in combination with Gloss coated paper demonstrated the largest gamut by quite a significant margin. Several other printers will be tested in the near future, and comparing gamuts of digital printers with the gamut of the gravure press is also scheduled.

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Author Biographies

Miro Suchy received his MS in Chemical Engineering and Pulp and Paper Technology from the Slovak Technical University (1994). After completing post-graduate training at McGill University (Montreal) he worked as Research Assistant at PAPRICAN/McGill University in Montreal, QC and as a Research Associate in Bio-products Division at IOGEN in Ottawa, ON. Currently he is studying at Western Michigan University.

Paul D. "Dan" Fleming is Associate professor in the Department of Paper Engineering, Chemical Engineering and Imaging at Western Michigan University. He has a Masters in Physics and a PhD in Chemical Physics from Harvard University. His research interests are in digital printing and imaging, color management and interactions of ink with substrates. He has over 150 publications and presentations and 1 US patent. He is a member of the IS&T, TAGA and the American Physical Society.