Optimal reproduction of spot colors on a digital press

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Abstract

Digital presses manufactured by companies such as Hewlett-Packard, NexPress, and Xerox are rapidly gaining acceptance in the marketplace. Since these devices typically use four or a few more colors in their printing processes, the degree to which they can accurately simulate the larger gamut of spot colors is of considerable interest in many applications. Pantone licenses printers at the end of an extensive color evaluation and analysis procedure, during which a lookup table is developed, giving the optimal inking values for matching or simulating each color of the PANTONE MATCHING SYSTEM®. The stability of the printing process over time gets a thorough test during this procedure, which uses both instrumental and visual matching techniques. Gamut mapping algorithms used in commercial profile-building software were developed for the reproduction of images, which are ensembles of colors; they do not usually yield optimal results for the case of individual colors. Development work at Pantone is aimed at a better understanding of how a skilled colorist makes the decisions leading to an optimal simulation of a color.

Introduction

The term "Digital Printing" commonly refers to two distinctly different approaches to turning digital bits into ink on paper, distinguished from other printing by their usefulness in "short run" printing. "Short run" may refer to an elastic definition of a number of sheets more than one and less than a truckload.

One approach may be called Integrated Mechanical Printing. Steps are taken to automate the mechanical printing press, by such means as including a plate exposing and delivery system right on the press, integrated packaging of inks, automatic paper handling, etc. Examples of such presses include offerings from KBA, Kodak, Screen, and Heidelberg.

The other approach is Variable Printing, which may be thought of as scaling up an office copier/printer to handle bigger and longer jobs. The core technologies include electrophotographic and ink jet printing. Some examples of these systems include Canon CLC 4000/5100 Digital Printers, Indigo presses from Hewlett-Packard, the Nexpress 2100 and 2500, and the Xerox DocuColor 7000/8000 and iGen3 Digital Production Presses.

Some workers in the field perceive that offset lithographic printing is considerably more complex and imprecise than well-controlled desktop printing,[1] while others think that offset printing is the higher-quality medium. Digital printing occupies the crossover domain between these broad classes. Can some meaningful statements be made about the comparative quality of these processes?

It is easy, when working in a software application like Quark, to select a PANTONE® Color from a drop-down menu and assume that color management will translate its CIELAB coordinates to process color inking values that will accurately reproduce the desired color on any printer; but this is often not the case. For digital printing, as for any printing process, a key quality measure is the degree to which it accurately produces the desired colors. PANTONE Colors are frequently used in the printing business, both as standard colors themselves for spot color printing,[2] and as measures against which process printing can be compared. The following paragraphs will attempt to explain this unique application of these colors.

The PANTONE Colors

In 1963, Lawrence Herbert was the new owner of a small, struggling printing company. He saw that printers could benefit from a collection of printed solid color ink samples with standard formulas and colors. He produced a fan-formatted book of 543 colors, and the PANTONE MATCHING SYSTEM was born. Printers and designers found it useful, and the collection was expanded – to 747 colors in 1987, and to over 1,000 colors in 1991. Except for metallic and fluorescent colors, the system consists of mixtures of 14 basic colors (see Table II). Fan-formatted books and chips sets are provided on gloss coated, matte, and uncoated papers, and they find use throughout the world in specifying solid, or spot color printing. Spot colors are especially useful for color-critical items like corporate logos. Examples found on the world wide web include IBM blue (PANTONE 2718 C), distinct from Microsoft blue (PANTONE 279 C), and PPG Industries blue (PANTONE 307 C).

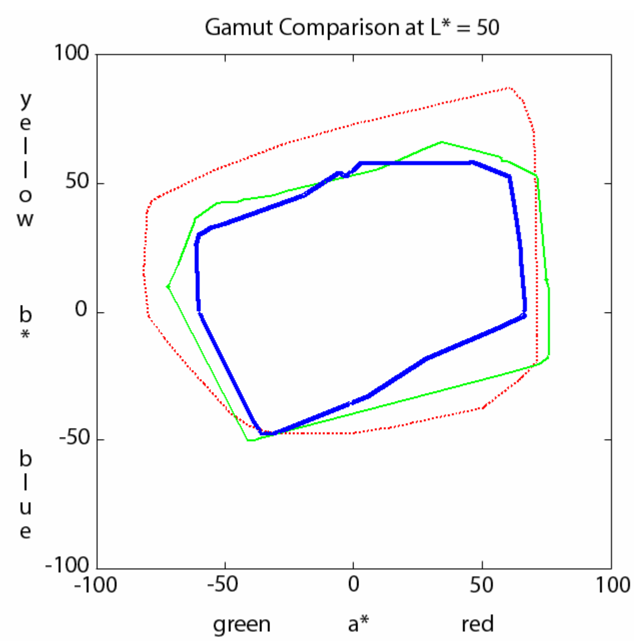

Figure 1. *Comparison of PANTONE formula guide (Red), Hexachrome (Green), and CMYK (Blue) gamuts at L* = 50*

The gamut of colors produced by this 14 primary set is naturally quite large, exceeding the gamut that can be produced by conventional printing with cyan, magenta, yellow, and black inks.

Figure 1 shows a comparison between the PANTONE formula guide colors and typical sheet-fed offset lithography with four colors on coated paper. Sixty-two percent of the 1089 PANTONE Colors (excluding fluorescent and metallic colors) are inside the four-color process gamut. (These in-gamut colors are identified by an icon [**::**] in the PANTONE formula guide.)

Running a print job with four process colors and a couple of spot colors requires at least a six-station press. Suppose, instead of spot colors, the extra stations ran additional well-chosen process colors. What would be the effect on the size of the process color gamut? For example, consider the Hexachrome® process invented by Pantone.[3] Hexachrome adds orange and green to a modified four-color ink set to produce the gamut shown in Figure 1. Eighty percent of the PANTONE formula guide colors fall within the gamut of this expanded process. Not only are more colors achievable by the expanded process, but the remaining out-of-gamut colors can be more closely approximated.

We live in an age afflicted by “mononumerosis;” we like to reduce every comparison to a single-number metric. What such statistics reveal may be interesting but may not be a sound basis for making a decision. The percentage of PANTONE Colors achievable by a particular printing process is like that. More information is needed to know what the pictures will look like.

While a lot of paper continues to be printed in conventional four-color offset presses, increasing amounts are printed in desktop printers or the short-run digital devices discussed earlier. (Among commercial printers, digital printing now accounts for 15% of sales.[4]) Pantone provides to manufacturers a service in which these devices are carefully characterized for optimum reproduction of colors, especially the Pantone set of solid colors. The goal is to satisfy the customer’s expectations for color, whatever the device that actually prints the job. The following paragraphs outline the process used.

Pantone Printer Evaluation Process

The process begins with a printing device, ink, and paper chosen to accurately represent the production run. The device is set up and calibrated in Pantone’s laboratory (see Figure 2) or, in some cases, at the manufacturer’s site, especially if the apparatus is large, as is the case with many digital presses. Shipping prints and data between sites imposes time delays on the process and requires good cooperation between the staffs at the manufacturer and at Pantone.

Once the printing device is operating to specifications, standard targets like that shown in Figure 3 are printed. The targets are measured on a typical spectrophotometer like the Gretag-Macbeth Spectrolino-Spectroscan[5] (Figure 4) and a profile conforming to the specification of the International Color Consortium (ICC) is generated with commercially-available proprietary software.

The B2A1 transform of the ICC profile is used to compute inking values for the Pantone colors, and a set of trial colors is printed. Figure 5 shows one of the 19 pages of this print. If the software and measurement were perfect, and if the printing device were perfectly repeatable, the process would be complete at this point. However, the in-gamut colors are often not reproduced as close to the aim colors as the printer is capable, and the simulations of some out-of-gamut colors are frequently not convincing.

***Figure 2**. Pantone Printer Laboratory*

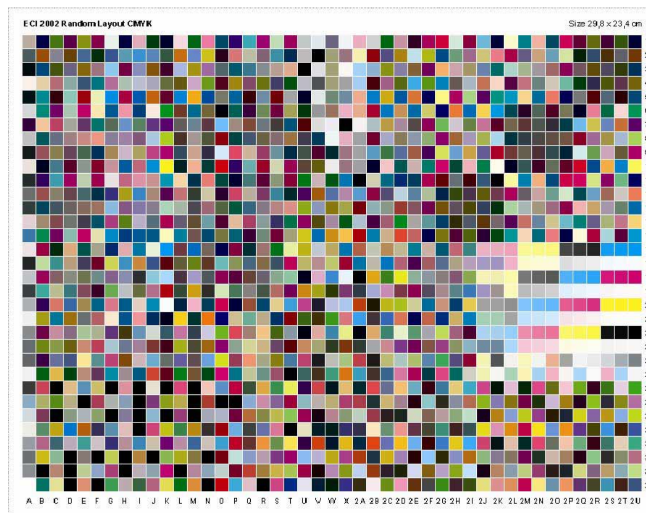

***Figure 3**. Characterization Target*

***Figure 4.** GretagMacbeth Spectrolino-Spectroscan*

Print-to-print, down-page and cross-page variations of the printer contribute to the differences, although using a randomized characterization target for profile building helps distribute these errors throughout the color space of the device. The modeling errors in the profile building software typically account for several ΔE of difference for in-gamut colors. The mapping of the out-of-gamut colors accounts for much of the remaining lack of satisfaction.

Figure 5. *Trial Colors Print*

Much has been written about gamut mapping, and this paper will not attempt to summarize this extensive literature. In most gamut mapping studies, however, there is an assumption, only sometimes made explicit, that the application is to reproduction of an image containing numerous colors. There are arguments that mapping the gamut of colors contained in an image ("image-dependent" gamut mapping) is preferable to mapping the whole space. However, the problem of simulating an out-of-gamut spot color on a process printing device is like the ultimate image dependent gamut mapping: the image is a single color! Think of the advertising executive judging her company's ad in a magazine by holding a PANTONE Chip next to her company's logo. The rest of the image is, for the moment, ignored.

Most of the pages of the PANTONE MATCHING SYSTEM publications consist of a full-strength color and dilutions of that color in white and black. The process of visually matching these colors is not strictly a single-color comparison, because the colorist takes account of the "flow" of the colors on a page, even if they are outside the printer's gamut. The simulations of these colors should retain a similar flow.

We have not yet found a mathematical technique that completely models what a skilled color analyst will do to adjust colors to simulate them with a palette that is capable only of a smaller gamut. We're looking. We measure the colors of the trial pass and of subsequent iterations, and we have accumulated a lot of data on the way this process works. We are experimenting with various models in an attempt to speed the process. A colleague has prepared a paper explaining some of his work on modeling, and we expect to see it published soon.

Once all 1,137 of the PANTONE formula guide colors are printed to the satisfaction of the color analyst, the adjusted inking values become the look-up table required to reproduce PANTONE Colors. Table I is an abridged example of such a look-up table. (An ICC Named Color profile for the device would incorporate this look-up table.) A customized interactive software program is prepared to illustrate the printer's gamut. The number of in-gamut colors is counted.

Table I. Abridged Look-up Table

C	M	Y	K	Name
0	2	99	0	PANTONE Yellow
0	9	96	0	PANTONE Yellow 012
0	63	91	0	PANTONE Orange 021
0	78	72	0	PANTONE Warm Red
0	83	68	0	PANTONE Red 032
0	98	31	0	PANTONE Rubine Red
	…			
8	7	0	39	PANTONE 877
0	13	16	29	PANTONE 8003
0	26	24	30	PANTONE 8021
29	45	27	0	PANTONE 8062
39	45	29	0	PANTONE 8100
30	8	0	40	PANTONE 8201
27	0	17	37	PANTONE 8281
18	0	20	21	PANTONE 8321

In addition to the 1,137 PANTONE Colors printed for each pass, a Digital Test Form (Figure 6) is also printed. Its inking values are fixed and do not change; measurement of its colors gives a quantitative evaluation of the stability of the process over time. Figure 7 shows a typical printer performance.

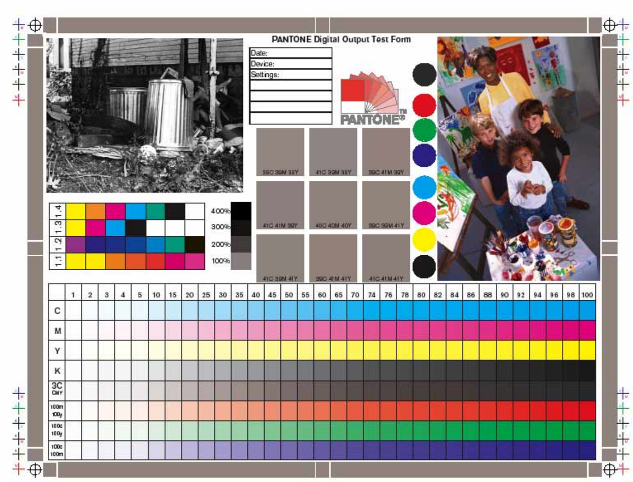

Figure 6. *Pantone Digital Test Form*

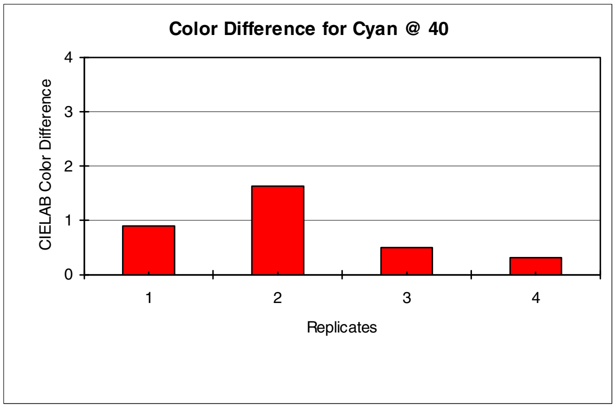

Figure 7. *Typical Printer performance*

Test target patches are measured with an image analysis system[6] and typical dot shape is reported along with actual area coverage. Figure 8 shows an example. Color analysis curves like those in Figure 9 are prepared to show the effect of concentration on color.

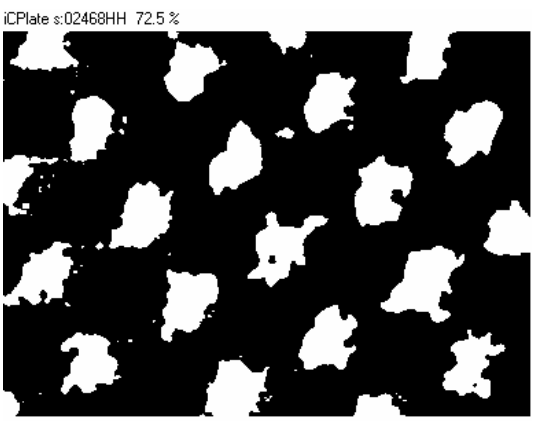

Figure 8*. Dot Area Nominal 80% Measured 72.5 %*

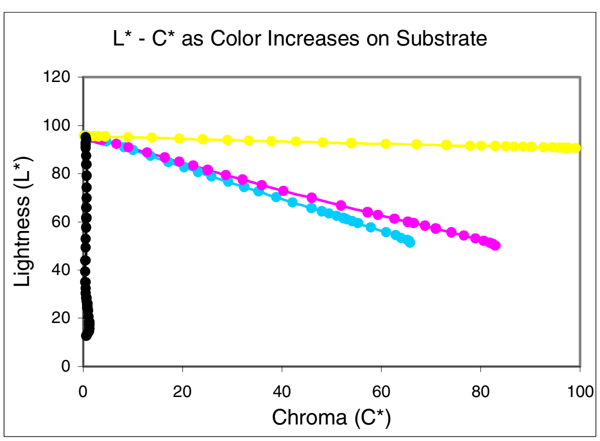

Figure 9. *Typical effect of Concentration*

Colors are computed for several illuminants to show how well the matches will hold up when the viewing conditions are changed from the Graphic Arts D50 standard. Table II lists an example.

Table II. Typical Metameric Index for Pantone Basic Colors

PANTONE Basic Color	D65	F2	A
PANTONE Yellow C	0.4	0.9	0.9
PANTONE Yellow 012 C	0.6	1.6	1.7
PANTONE Orange 021 C	0.3	3.1	0.6
PANTONE Warm Red C	0.1	0.8	0.2
PANTONE Red 032 C	0.4	0.7	0.7
PANTONE Rubine Red C	0.6	3.5	1.7
PANTONE Rhodamine Red C	0.1	0.4	0.1
PANTONE Purple C	0.7	4.6	2.1
PANTONE Violet C	0.1	1.6	0.6
PANTONE Blue 072 C	0.5	6.3	4.8
PANTONE Reflex Blue C	0.1	5.0	3.1
PANTONE Process Blue C	0.4	0.6	0.8
PANTONE Green C	0.5	2.6	0.8
PANTONE Black C	0.7	3.4	2.5
Average	0.4	2.5	1.5

Evaluation Results

A comprehensive report of all these test results is prepared for each printing system tested at Pantone. The information is treated as confidential between Pantone and the printer manufacturer; the manufacturer decides the use for the information and what to disclose to the public.

The digital presses certified by Pantone to date include:

Hewlett-Packard Indigo and Indichrome
Nexpress 2100+ and 2500
Xerox DocuColor 6060 and 8000, Xerox iGen 3

References

[1] R. S. Berns & D. M. Reiman, Color Managing the Third Edition of Billmeyer and Saltzmann's Principles of Color Technology, Color Research & Application 27, p.371 (October 2002)
[2] Computer Arts (UK), 01/04/2006, p. 60-61
[3] U.S. Patent number 5,734,800
[4] H. Tolliver-Nigro, "Innovations in Offset," Ink Maker 84, p. 12 (May 2006)
[5] GretagMacbeth GmBH, www.gretagmacbeth.com
[6] Beta Industries Ultra Dottie II, www.betascreen.com

Author Biography

John Setchell manages the development of advanced color technology at Pantone. Before joining Pantone, he was at Kodak, where he developed innovative process control for color electrophotographic printing systems, magnetic recording and thermal dye printing systems for electronic photography, and color management systems for digital imaging. He has degrees in physics from Rensselaer Polytechnic Institute and the University of Illinois and is a retired U.S. Naval Reserve officer, a Sea Scout leader, and a cross-country skier.