Digital Offset Printing – Going Beyond 4 Colors

Galia Golodetz; HP Indigo Division; Israel
Ehud Chatow, Kok-Wei Koh and Ingeborg Tastl; Hewlett-Packard Laboratories; Palo Alto, California

Abstract

While 4-color CMYK printing is the norm for mainstream offset printing, all HP Indigo digital presses have the option of printing with up to 5, 6 or 7 different colors. These extra color stations can be used to improve image quality by increasing the color gamut, decreasing graininess, reducing illumination sensitivity, or adding special effects to the printed output. The HP IndiChrome Pantone® certified ink mixing system is one key enabler of these improvements, allowing customers to create Pantone® or custom-matched spot colors at their own site.

In this paper, we show how the color gamut of a digital press can be increased through the use of additional full-density inks, such as green and violet. We also show how the graininess of a print can be decreased through the use of light inks. In particular, we show how the addition of a gray ink can decrease the illumination sensitivity, improve the gray neutrality, and reduce the graininess of a print. Finally, we highlight some of the special effects that can be created when using specialty inks such as the digital matte ink.

Introduction

With the subtractive color system that is used when printing on white paper, three primary colors (cyan, magenta and yellow) are required to create a wide range of colors. Because black text is often used on printed materials, a black ink was added to the set, thus creating the standard 4-color CMYK ink set that dominates the printing industry today. The black ink also serves to expand the color gamut in the dark regions due to the fact that the primary inks are far from ideal – that is, they absorb light in regions of the visible spectrum in which they are supposed to reflect and vice versa. These unwanted absorption and reflection characteristics also define the size and shape of the color gamut – the range of colors that a particular device, using a particular set of inks and paper, is able to reproduce. For commercial offset printing, various standards have emerged which define the recommended behavior of ink and the size and shape of the color gamut. In the United States, the SWOP standard (Specifications for Web Offset Publications) is often used, while in Europe, the Euroscale standard is preferred.

While merely adhering to these standards can satisfy a large percentage of applications, there are many others that are limited by them and can benefit from expanding beyond the traditional 4-color printing process. Commercial offset printers often use additional spot inks for more accurate reproduction of corporate logos. High quality black and white photography books are often printed with duotone, tritone and even quadtone processes. However, digital presses have largely been relegated to simple 4-color CMYK printing. With HP Indigo digital presses, this does not have to be the case.

HP IndiChrome Ink Mixing System

The ability to print special colors is one of HP Indigo's significant differentiators. HP Indigo digital presses allow for up to three more ink systems to be added to the 4 basic process colors, making the presses capable of printing with up to seven colors. A set of special inks, such as orange, violet, blue, green, rhodamine, bright yellow and transparent, is an option. Those colors can be used as additional process inks, or can be mixed (also with CMYK) in order to create spot colors. All inks are approved by Pantone® for blending simulations of Pantone® colors.

The greatest need in printing spot colors is for our industrial label printers, where very specific custom colors are often required. Custom colors are typically used to provide identification and authenticity, for example corporate logos, or specifically to catch the eye of the final customer. For example, the corporate colors of various credit cards, such as "Visa blue," "Visa yellow," or "MasterCard red," all require very accurate color reproductions.

Advantages of spot / mixed colors over halftone process color matching and printing include the following:

1. Solid areas with better uniformity.
2. Improved fine lines and text quality.
3. Extended color gamut with extraordinary vibrancy and eye catching effects.

For the reasons listed above, HP Indigo offers its customers a specially designed HP IndiChrome Ink Mixing System, consisting of some hardware and software, and utilizing a common language with the variety of digital presses.

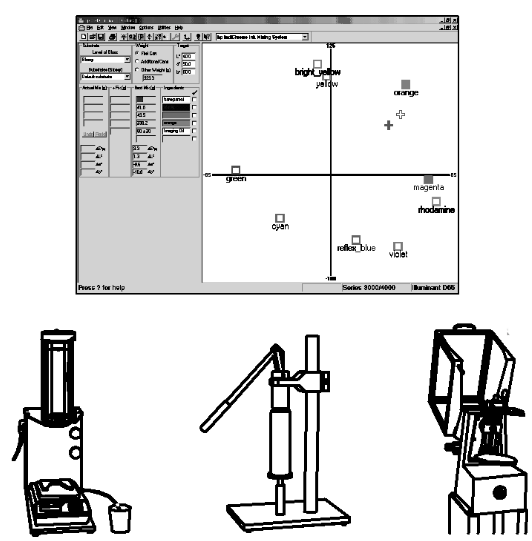

Figure 1. *HP IndiChrome Ink Mixing System; (top row): software (bottom row): dispenser, crimper, shaker.*

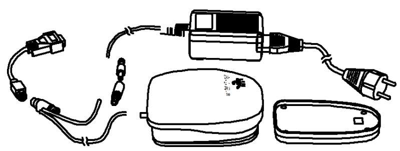

Figure 2. *Spectrophotometer.*

Figures 1 and 2 show the components of the system, which consists of the following components:

- Software – calculates the amount of each base ink needed to match a given Pantone® named color or CIELAB value
- Dispenser – dispenses precise amounts of base inks into the receiving can
- Crimper – seals the receiving can with a valve
- Shaker – mixes the contents of the can until a homogeneous mixture is attained
- Spectrophotometer – measures the color of a printed swatch

The process of color preparation

After choosing a substrate type, the desired illuminant and color observer, the user has three options for specifying the desired color: they can measure a sample of the desired color patch with the spectrophotometer, they can specify the desired CIELAB values directly, or they can select a specific Pantone® named color from a drop down menu. This flexibility obviates the need to take measurement from swatch books and eliminates errors due to the use of damaged or faded books.

After the software generates the formulation, the exact amounts of inks are dispensed into a new can. The can is closed by the crimper and shaken for a few minutes. The mixed can is inserted into the press and the sample color patch is printed. The press parameters for the specific ink are defined in the ink definition file, which is also created by the software. After the ink is printed, its spectrum is read with spectrophotometer, and if a small adjustment is needed, the software will recommend it. The adjusted ink is prepared as described above, added to the ink tank and the final color is printed.

If the target color is extremely saturated, the software might recommend printing a double hit of ink (applying two layers of ink to the paper) which would produce a closer match to the target color. The software uses a unique iterative algorithm, which suggests the least metameric choice and also takes into account that when the basic inks are mixed with certain fractions in the ink tank, they will not always appear on the printed page with the same fractions.

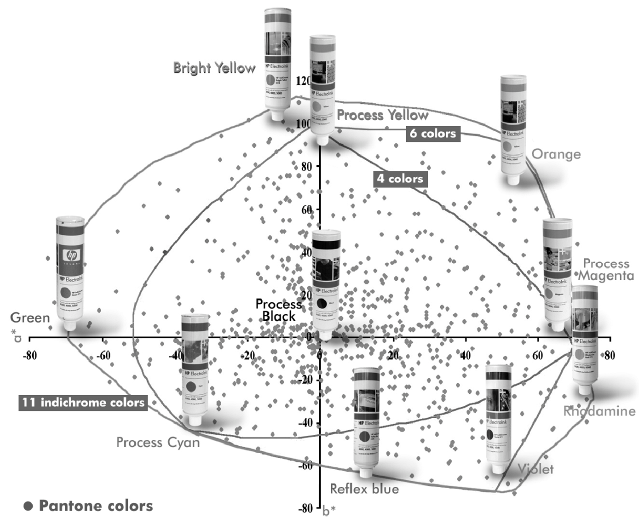

Figure 3. *Pantone® coverage using 11 IndiChrome inks.*

Extended Print Solutions

The ability to add up to 3 additional inks in combination with the ability to mix customized inks using the HP IndiChrome Ink Mixing System enables a whole variety of new extended print solutions. These include the possibility to add spot colors, an invisible ink and different amounts of gloss, all within one printing process. Naturally, additional inks can not only be used by themselves but also be combined with the commonly used CMYK ink set. This results in the capability to produce more chromatic images, which is important for photo-related applications. Yet another possibility is to add a gray ink, which is extremely beneficial for black and white printing. The specifics of these applications will be discussed in the following 3 subsections.

Spot Colors

Using combinations of the 11 IndiChrome inks, it is possible to generate colors that cover 95% of the Pantone® coated palette, applying a double hit where needed. This allows customers to generate virtually any Pantone® color to match their corporate logo, or to create exact matches for graphical elements.

In addition, HP Indigo provides a series of special inks that enable our customers to differentiate themselves from their competition. These include some daylight fluorescent colors, invisible ink (fluorescent under UV), the Indigo Digital Matte, and the recently announced light cyan, light magenta inks. The light inks help to dramatically lower the grain and increase the smoothness of any image or graphic. The recently introduced Indigo Digital Matte enables a straightforward approach to achieve a differential gloss. As an example, by printing on a standard coated substrate with 75 gloss units, the solid ink image would naturally comply with the substrate topography and result in a similar gloss level. Adding a single hit of the Digital Matte ink will result in a reduction of 45 gloss units and create a differential gloss effect. This can further be enhanced by applying additional layers of this Digital Matte ink as part of the printing process.

Gamut Expansion with Additional Primaries

For some applications (e.g. printing of photo books or highly chromatic labels and packaging), the availability of a color gamut that goes beyond a traditional offset gamut is a desirable feature. In the case of the Indigo, additional full density primary inks can be added to the default CMYK set, and in combination with an adequate separation, a significant increase in gamut size can be achieved. As an example, Figure 4 visualizes the gamut gain achievable by adding an additional green and violet ink.

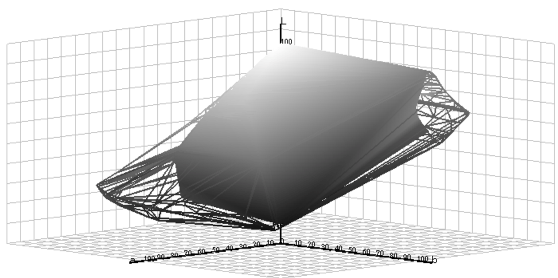

Figure 4. *Gamut using CMYK (solid) versus gamut using CMYKGV (wireframe).*

Obviously, images with bluish content like sky and water can be reproduced in a more chromatic way, which is commonly preferred by average consumers. Figure 5 depicts the increase in the form of a projection of the two gamuts onto the a*b* plane.

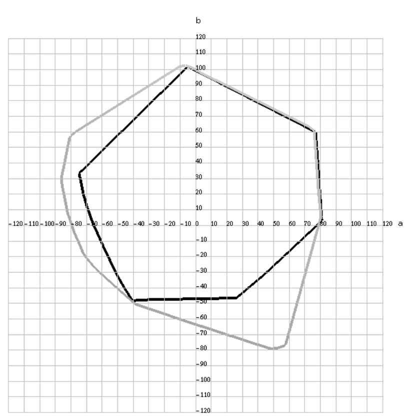

Figure 5. *Gamut using CMYK (black wireframe) versus gamut using CMYKGV (gray wireframe).*

Comparing the new gamut with that of a typical silver halide paper, the benefits of adding violet and green inks become obvious (Figure 6).

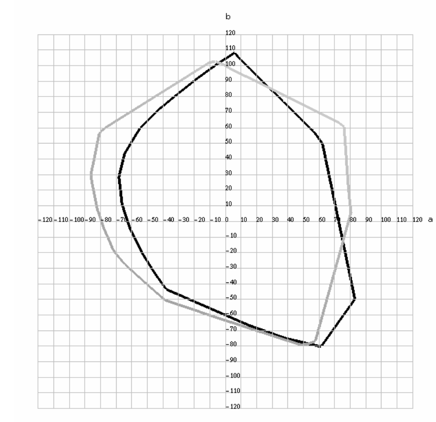

Figure 6. *Gamut using CMYKGV (gray wireframe) versus gamut using AgX (black wireframe).*

Again, this is just one example. Depending on the specific application, a print shop provider select a different set of additional primaries, or mix a custom ink that best meets their specific needs. This is a unique capability which is only available on digital presses from HP.

Gray Ink for Enhanced Black and White Printing

In 2002, we showed that the addition of light cyan and light magenta ink is an effect way of reducing grain and achieving smooth photo-quality output on a digital press [2]. Since then, we have extended these studies by experimenting with the use of a gray ink. The addition of a gray ink brings forth many advantages, which include the following:

1. reduction of grain, particularly along the neutral axis
2. better gray neutrality along the neutral axis
3. decrease in illumination sensitivity
4. possible decrease in ink use (compared with heavy use of composite ink)
5. the ability to use gray as a spot ink for text and graphics

For our experiments, we used a Pantone Cool Gray 9C ink, which was created using the HP IndiChrome Ink Mixing System. Four different separations were then created specifically for black and white printing: 4-color CMYK, 1-color black only, 2-color gray and black, and 7-color CMYKcmg. For the 4-color CMYK separation, a medium GCR setting was used, black ink was introduced at 20%, and a maxium of 400% ink was allowed. This generally provides a good balance of low grain, smooth transitions, and good neutrals.

To test these 4 different ink combinations, the black and white image shown in Figure 7 was used.

Figure 7. *Sample black & white image that was used for testing the four different ink sets and black generation methods.*

The part of the image that is circled shows the top of a building in Chicago. Zooming into this part of the image, we see that there is an advertisement on the top of the building for “Condos for Sale” followed by a phone number.

Figure 8. *Close up of the top of the building showing fine text and numbering.*

The image was printed to fit on a 12”x18” sheet of paper, which resulted in the above section covering an area of only .2”x.35”. The four different separations gave distinctly different results. When viewed under a loupe, this is how they look:

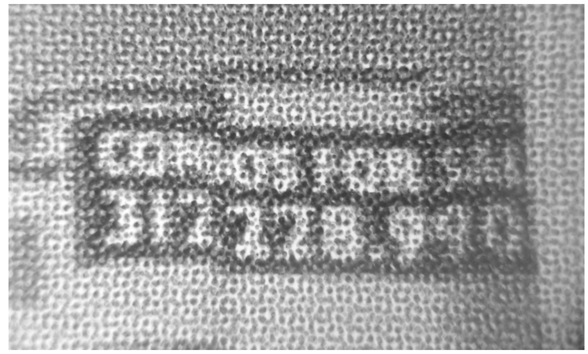

Figure 9. *Magnified view of the 4-color CMYK printed output.*

Using the traditional 4-color CMYK process, you can see the characteristic rosette halftone patterns throughout much of the image. In addition, it is fairly difficult to make out the words and numbers of the billboard. Relying too much on composite black (using CMY ink for the neutral axis) could also result in a color cast when printing black and white images. The only alternative in the case of a 4-color device is to use only black ink for the neutral axis.

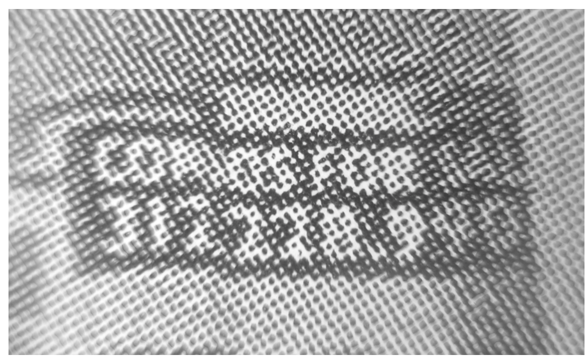

Figure 10. *Magnified view of the K-only printed output.*

Here, we see the results of using only black ink for the neutral axis. While the resulting image is extremely neutral, even under different illuminations, it has an overall grainy look and lacks detail throughout. The image also lacks dynamic range due to the fact that black ink by itself is not as dark as black ink on top of cyan and magenta.

Figure 11. *Magnified view of the 2-color black and gray printed output.*

With the addition of a gray ink, we get a vast reduction in grain while maintaining a smooth neutral tone throughout the tonal range. The fine text and numbers also become much more detailed and legible, and the dynamic range improves over the black-only print. Furthermore, the 2-color gray and black printing process has the advantage of requiring only two impressions on the Indigo digital press, resulting in the doubling of productivity over the traditional 4-color CMYK process.

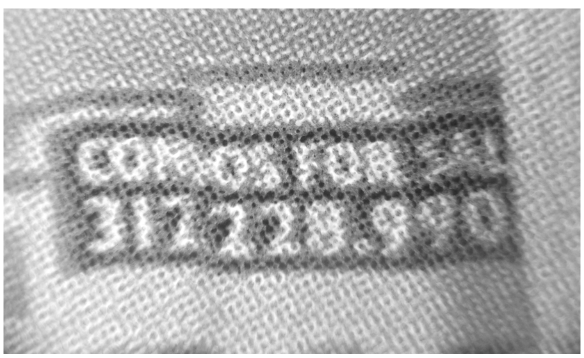

Figure 12. *Magnified view of the 7-color CMYKcmg printed output.*

The final test involved using all seven ink stations available in the HP Indigo 5000 press. The results were very impressive. The image showed minimal grain, deep blacks, neutral grays, and excellent detail. Such a setup can also be used to print stunning color images. In fact, this exact setup was used to print an 88-page color catalogue for the photography exhibit "Joel Meyerowitz: Modern Color Vintage Prints," which was held at the Edwynn Houk Gallery in the spring of 2006 in New York. The front and back covers were printed with 7-color CMYKcmg, while the inside pages were printed with 6-color CMYKcm for the color photographs and Pantone Cool Gray 9C spot ink for the text.

Conclusion

The ability to print with more than 4 colors opens up a whole new world of possibilities. With support for ICC color management, today's digital workflows allow for accurate and consistent reproductions, regardless of the input color encoding. Future workflows will allow for automatic color separations into any arbitrary set of inks that are installed in the press. By providing extended capabilities and enhanced image quality, the user now has the choice of optimizing for cost, speed or image quality. We have only scratched the surface of what's possible in the world of digital printing and publishing. With HP's Indigo technology, we are well positioned to venture into new realms and make those dreams a reality.

References

[1] G. Golodetz and U. Chatow, Creating Value for our Digital Label Printers, DPP 2005.
[2] A.U. Agar, G.J. Dispoto, I. Tastl, K.W. Koh, N. Damera-Venkata, Photo Quality Printing on a Digital Press, Proc. NIP18, pg. 87-90 (2002).
[3] U. Chatow, The Fundamentals of HP Indigo's Digital Offset Color Printing Process and How it Rivals Mechanical Offset Printing, Proc. NIP18, pg. 125-129 (2002).
[4] User guide, HP IndiChrome Ink Mixing System

Author Biography

Galia Golodetz received her B.Sc. degree in Chemical Technology from the Shenkar College of Engineering in Ramat Gan, Israel and M.Sc. in Technology Management from New York Polytechnic University. Since 1988 she has worked at Indigo (now part of HP) Israel in several R&D positions, and her current position is Manager - Special Inks and Industrial Applications R&D.

Ehud Chatow received his B.Sc. and M.Sc. degree in Physics from Tel Aviv University and his MBA from Kellogg / TAU. Since 1988 he has worked in Indigo (now part of HP) Israel in several R&D positions among them Project Manager, Ink Department Manager, R&D Materials Section Manager and is now in HP labs.

Kok-Wei Koh earned his B.S. with distinction in Computer Science (magna cum laude) from the University of Washington, Seattle, in 1994, and his M.S. in Computer Science from Stanford University in 2002. He has been working in the Digital Printing and Imaging Lab of Hewlett-Packard Laboratories since 2000, where he conducts research experiments on all things color related.

Ingeborg Tastl is a senior color scientist at Hewlett-Packard Laboratories working in the area of digital imaging and printing since April 2001. Before that her focus point was in the area of digital photography while working at Sony's US Research Laboratories and at the Ecole Nationale Superieure des Telecommunications in Paris. She got her M.S. degree and her Ph.D. degree in computer science from the Vienna University of Technology, in Austria. She was the SID General Chair for the 2002 IS&T/SID Color Imaging Conference.