Methods and Mechanisms of Expanding Destination Color Gamut in HF Color Printing

LI Xiao-zhou[1,2], CHEN Guang-xue[1], 1, State Key Laboratory of Pulp and Paper Engineering, South China University of Technology, Guangzhou, 510641, China; 2, School of Light Chemistry and Environment Engineering, Shandong Institute of Light Industry, Ji'nan, China*

Abstract

Gamut compression is to map the larger gamut of original to the smaller gamut of destination in color digital printing. To guarantee high quality of reproduction, color match is required to be done as well as possible. We can expand the destination gamut by using different methods, for instance, improving paper properties, improving printing technologies, selecting better inks and adopting high fidelity color printing technology which uses more than 4 inks (i.e., 4 + x) to print. In this paper, we performed experiments and theoretical studies to verify the process using CMYK and spot colors model to achieve HF color printing. The color gamut characteristics of the above model, CMYK and spot color inks, were analyzed. We also studied the theoretical basis of spot color selecting methods and the influences of various methods on expanding destination gamut, which included using different color gamut mapping methods, using novel halftone technique, adding new primary inks and selecting suitable papers. Experimental showed that the range and result of destination gamut expansion of the above methods were different. Using modified screening methods and more than four colors printing, 4+x high fidelity printing could achieve the best optical effect of printing image.

Introduction

Color gamut is the range of colors achievable on a given color reproduction medium or represented in an image on the medium or contained in an image under a given set of viewing conditions. And it is one of the most important characteristics to represent color information and is one of the most important targets to control in color transmission process. Color gamut can be either considered as the basic characteristics of original image or be considered as one of the main factors of evaluation of color representation in color transmission and reproduction process. Color gamut can be classified into source gamut and destination gamut according to the relations of color position in color transmission process [1-2]. Source gamut is defined as the range of colors contained in original image or colors represented by image capture device or image display device, while destination gamut is defined as the range of colors of contained in output device or printing reproductions. The relations between source gamut and destination gamut can be classified mainly into gamut compress and gamut expansion. Gamut compress is to map the bigger source gamut to the smaller destination gamut, which could consist of gamut clipping and gamut compress. On the contrary, gamut expansion is to map the smaller gamut to the bigger gamut or to expand the destination gamut by special techniques. Gamut compress and gamut expansion are both common gamut mapping techniques in color reproduction.

In color printing, Cyan, Magenta, Yellow and Black inks are always used to reproduce the colors. These four color inks determine the range of color space of printing colors. Ideally, we can perform all color reproductions and exact matches of source gamut and destination gamut by using Cyan, Magenta and Yellow inks according to the principles of subtractive color process. However, there is a great difference between the practical spectrums of the inks and the ideal spectrums in practical printing process. The effect of secondary colors achieved by Cyan + Magenta, Cyan + Yellow, Magenta + Yellow and Cyan + Magenta + Yellow (i.e., Blue, Green, Red and Gray) has great difference from the ideal colors [3]. The difference between destination gamut achieved by four primary color inks and source gamut of the original sometimes is great. The color gamut match can be improved and the color distortion can be reduced in color transmission process by using some special techniques, such as the output control technique of prepress, image enhancement technique, gamut mapping technique and color management technique. Furthermore, we can expand the destination gamut through variations of methods which includes improving paper properties, improving printing technology, selecting good inks and using more than 4 color inks printing technology (i.e., high fidelity printing of 4 + spot color printing technology).

There are several studies focusing on the development and improvement of gamut mapping algorithms between source gamut and destination gamut in the existing high fidelity printing process. For instance, color signal is transferred from the traditional color image signal to the high fidelity image signal based on high-definition TV (HDTV) standard [4]. In this paper, several experiments using 4-color inks and spot color inks to achieve high fidelity printing were performed and the related mechanisms were studied. And the color gamut of 4-color inks and spot color inks was presented. Some new screening technologies were used and new primary inks were adopted based on many experiments of high fidelity printing and different types of papers were also used in this paper. It found that the appropriate methods should be selected to expand the destination gamut according to the relations between the source gamut and the destination gamut.

Main Methods and Mechanisms of Destination Gamut Expansion

Main methods of destination gamut expansion

Destination gamut, which is versus source gamut, is the range of color information contained in destination mediums or substrates (Fig. 1). In Fig.1, the destination gamut is represented by CMYK mode. The influential factors of destination gamut mainly include output device, paper, ink, halftone technique and gamut mapping, etc. In a practical printing process, destination gamut also can be considered as a combination of the above factors rather than only one factor. The size and shape of destination gamut are different when to use different types of papers, inks or different halftone techniques and different gamut mapping algorithms in the same printing process (Fig. 2).

For the same output device, its destination gamut is fixed. So it is necessary to change printing technology or use more primary inks to expand the destination gamut. In this paper we classified the methods of expanding destination gamut into software mode and hardware mode. Software mode mainly focuses on the researches on the gamut mapping algorithms. For instance, different gamut mapping algorithms are used in the process that color signal is transmitted from one display device to another and video signal is transmitted from CRT to HDTV.

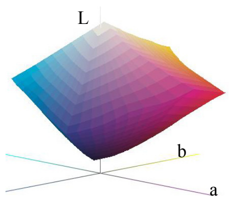

Figure 1 *Gamut of CMYK Color Space*

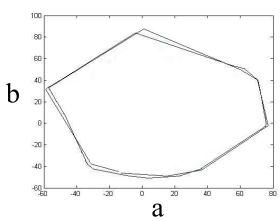

Figure 2 *Gamuts of two different types of papers using Epson Stylus Pro7880C*

There are several common algorithms such as true-color gamut expansion algorithm, same drive signal algorithm (SDS), hybrid color mapping (HCM), chroma and lightness-chroma adaptive algorithm [5]. Hardware mode is mainly refers to the techniques used to achieve destination gamut. For instance, multi inks using more than 4 color inks (i.e., 4-color inks + spot color inks) are used to represent colors in printing process. Digital inkjet printing and high fidelity printing are two methods of this type. Improve screening resolution and screening mode and use novel screening technique can expand the destination gamut [6-8]. For instance, use frequency conversion amplitude screening (FCAM) according to AM and FM [6]. We can also select presses of high performance and new printing materials and use different types of papers to perform high fidelity printing.

Main mechanisms of destination gamut expansion

In the color printing process, we mainly use novel halftone techniques and select or increase new primary inks to perform destination gamut expansion. And selecting or increasing new primary inks is based on color separation techniques. Novel halftone technique combines the software mode and hardware mode together to get the destination gamut. Compared with traditional amplitude modulation (AM) halftone technique, novel halftone technique has made a breakthrough in the range of color reproduction, printing density, printing definition and image level. Generally speaking, the novel halftone technique is mainly refers to frequency modulation (FM) halftone technique which can represent the fine detail and achieve the good visual effect of image. FM technique is not limited by screening angle so that it can represent much wider range of color gamut. Consequently, FM technique is one of the key technologies in digital inkjet printing and can be used to achieve multi-color printing, i.e., more than four color inks printing. At the same time, destination gamut can be expanded according to the method that changes screening resolution of different color plate based on AM. This method is called as frequency conversion amplitude modulation screening technology (FCAM) in Pro. CHEN Guang-xue's researches [9-10].

Furthermore, high fidelity color separation technique is one the most important techniques in expanding the destination gamut [11]. There are two main types of color separation modes at present. One is that to set color separation model in interaction graphical user interface which takes ICISS as representative. The other is fixed color separation model based on high fidelity color lookup tables (CLUTs) which takes Pantone Hexarome as representative. There are some bigger color differences in color representation using Pantone Hexarome model to separate color which even causes lightness of some colors to change greatly according to some researches and practical experiences. Some high fidelity color separation techniques developed recently can achieve one separation model with up to 16 primary colors. Several common high fidelity printing techniques are as follows:

The technique using new CMYK inks of high purity;

MAX CMY technique;

Increase OGB inks as the primary color inks, i.e., orange ink, blue ink and green ink;

Hexachrome technique (i.e., CMYK + OG). It increases green ink and orange ink of Pantone Hexachrome based on CMYK.

Strictly speaking, the first two techniques still belong to common printing process rather than high fidelity printing technique as they use the better inks, i.e. they only improve the ink properties without using novel color separation technique and screening technique. The latter two increase some spot color inks based on common CMYK inks to expand the destination gamut so they both belong to high fidelity color printing.

Experimental and Discussion

The result of destination gamut expansion performed by different color gamut mapping methods, different types of paper, novel screening technique and more inks was analyzed according to the common methods and mechanisms in high fidelity printing process in this paper. Epson Stylus Pro7880C was used to output the original, ECI2002R CMYK testchart, onto six paper samples (Table 1) using Epson UltraChrome K3 VM ink. The work environment was in EFI workflow and the color image signals were displayed using EIZO ColorEdge CG211, which guaranteed the data reliability. The output color data were measured by using X-Rite Eye-one io under the condition of D65/2° and three ICC profile were made by using ProfileMaker5.0.8. The gamuts were obtained in Matlab2008a.

Color gamut mapping methods effect on destination gamut

Generally speaking, the range of destination gamut is fixed in specific printing process. However, when different color gamut mapping methods were used in the workflow based on ICC color management system, the ranges of destination gamut were different (Fig.3). In Fig. 3, the yellow range was got by LOGO Classic color gamut mapping method and the red range was got by LOGO Colorful gamut mapping methods. Both were in the EFI workflow embedded ICC profile and the ECI2002R CMYK was output by Epson Stylus Pro 7880C. We found that the yellow range was wider than the red range in green area of ab plane. So it is important to pay more attention to color gamut mapping methods and algorithms to expand destination gamut in the workflow based on ICC color management.

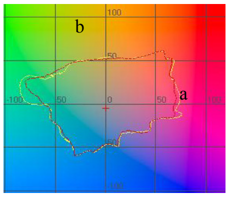

Figure 3 Destination gamuts of different gamut mapping methods

Papers effect on destination gamut

Six types of papers were used in this experimental, Table 1. And six destination gamuts were got by using Epson Stylus Pro 7880C to output the ECI2002R CMYK test form, Fig.4. In Fig.4, we found that, the destination gamut of 2# and 3# paper sample was wider than that of 6#, and the destination gamuts of 2# and 3# paper sample were similar while the destination gamuts of 1# and 5# paper sample were similar too. The six gamut shapes were similar. It denoted that different types of paper had great effect on destination gamut expansion.

Table 1 paper samples

Paper sample number	Paper sample type
1#	Imitation coated art paper
2#	Quantitative paper of 180g meeting EU standard
3#	Waterproof matte coated proofing paper
4#	Matte paper
5#	Semi-matte paper
6#	Semi-matte proofing paper

High fidelity technique effects on destination gamut

High fidelity is versus four color printing technique. In four color printing, cyan ink, magenta ink, yellow ink and black ink are used to perform the printing process. As the existing papers and inks can't represent the whole gamut of the original, novel halftone technique and new primary inks are used in high fidelity printing process in order to improve the saturation of some colors. For instance, red ink, green ink and blue ink are added to the primary inks and frequency modulation screening method and FCAM halftone are used to make the contrast of the printing image more natural and the color more vivid.

Image halftone technique is one of the core techniques in digital image output process, which plays an important role in the representation of the image color and level. The halftone image of more than four color inks (e.g., six color inks or seven color inks) can be output by using modified screening techniques. And moiré pattern can also be avoided by using the novel halftone technique [9]. FCAM halftone technique was used in this paper to achieve high fidelity printing without changing the existing printing techniques and devices. And the destination gamut of reproduced image was wider and the image transmission result was more vivid. The process was described as follows:

Step 1: For different halftone images, still use AM halftone technique;

Step 2: Change the resolution of different halftone images;

Step 3: Overlay the different halftone images with smaller screening angle differences or even the same angles.

In the experimental of FCAM solution, cyan halftone image, magenta halftone image, yellow halftone image, black halftone image and three halftone images of spot color layout were used. The screening resolution and screening angles were as follows:

Set 225 LPI as the basic screening resolution for CMYK layouts, and set the screening angles of the four layouts as Y (0°), M (15°), C (75°) and K (45°) separately. Set 133 LPI as the screening resolution for the three spot colors and set the angles of the three spot colors as spot1 (15°), spot2 (75°) and spot3 (45°) separately. The destination gamut was expanded as the three spot color inks, red ink, green ink and blue ink, were added in the high fidelity printing using four color inks and three spot color inks (Table 2 and Fig. 5) [9,12].

In Fig. 5, the range of destination gamut of high fidelity printing is much wider than that of common four color printing, which denoted that the high fidelity technique expanded the destination gamut greatly and maintain the good shape similarity of the destination gamut before and after expansion.

Table 2 Chromaticity coordinates of 4-color and 7-color patches

color patch	X		Y	
	4-color	7-color	4-color	7-color
y	0.4689	0.4769	0.4984	0.5115
r	0.5933	0.6263	0.3391	0.3375
m	0.4740	0.4376	0.2437	0.2022
b	0.2030	0.1700	0.1691	0.1274
c	0.1604	0.1497	0.2386	0.2531
g	0.2468	0.2390	0.5353	0.6478

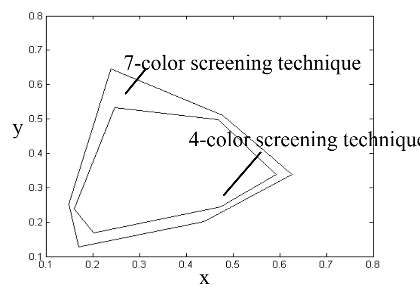

Figure 5 Color gamuts of 7-color screening technique and 4-color screening technique

Primary inks effect on destination gamut

Ink is one of the most important elements in the presentation of the destination gamut. High fidelity color printing requests that ink should have enough lightness to expand destination gamut. As a result, we should select the suitable ink which has the maximum of PC×Y. PC is the purity of ink and Y is the lightness. So the ink selected according to the above not only meets the higher lightness and higher saturation. Several spot color inks are used in digital inkjet printing technique to improve the lightness and saturation of the color, which meets the requirements of high fidelity printing. The special inks for Epson were used to get the destination gamut in this paper (Table 3 and Fig. 6). In Fig.6, the smaller destination gamut was got by 4 inks sample, such as I1#, I2#, I3# and I4# ink and the larger destination gamut was got by the eight inks sample.

Table 3 Epson color inks

Ink sample number	Ink sample type
I1#	Photo Black
I2#	Cyan
I3#	Vivid Magenta
I4#	Yellow
I5#	Light Light Black
I6#	Light Cyan
I7#	Vivid Light Magenta
I8#	Light Black

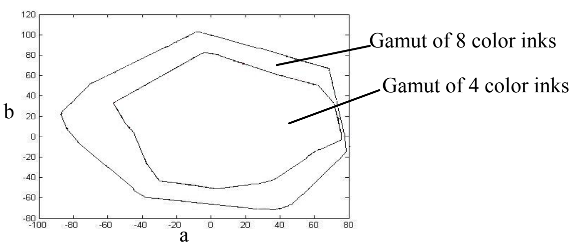

Figure 6 *Gamuts of four color inks and 8 color inks*

Conclusion

From the experiments in this paper, we found that the destination gamut expansion mechanisms are different, especially between high fidelity printing and common printing. In the destination gamut expansion of different displays, color signal are transmitted from the display based on EBU standard to the display of wide gamut based on xvYCC standard. In such process, color signal is made up of Red , Green and Blue, which still belongs to additive color process. However, in high fidelity printing process, display of wide gamut or narrow gamut works as the source devices, and the gamut of printing products are the true destination gamut. Consequently, destination gamut mapping algorithms has no practical meaning to expand the destination gamut of high fidelity color printing as the existing color signal transmission between display and display or display and projection is still based on RGB signal. The destination gamut expansion of printing products is mainly achieved by hardcopy output techniques or other printing technologies.

It found that modified halftone techniques, more than four color inks printing (i.e., 4+x high fidelity printing) and printing devices of high performance and novel printing materials had varying effect on destination gamut expansion. The expansion direction and range of destination gamut was different too. The destination gamut obtained by different papers maintained shape similarity best among the methods in this paper, while the expansion of destination gamut by using high fidelity printing technique which includes increasing primary inks and using modified halftone techniques is the most obvious.

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Author Biography

LI Xiao-zhou (1981-), male, received a BEng (Hon) in graphic communications engineering (2004) from Shandong Institute of Light Industry. He received his Master's Degree in Pulp and Paper Making Engineering (2006) from Wuhan University. He is currently a PhD candidate of South China University of Technology. And he is an instructor of Shandong Institute of Light Industry. His work focuses on color image processing, digital printing technique, etc.
Email: lixiaozhou2000@163.com.

Chen Guang-xue(1963-), male, doctor, professor. Now, he works in South China University of Technology ,Guangzhou, China. He is a member of Chinese Society for Image Science and Technology(CSIST) . His work focuses on color image process, digital printing technique and so on.
Email: guangxuecn@yahoo.com.cn.