Research on the halftoning method to achieve high-fidelity printing

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Abstract

We can extend ink color development space by using high purity, other than the four-color ink and more than four-color separations and halftoning replication methods in order to more accurately reproduce the original color. A new printing images halftoning method of frequency modulation amplitude modulation was studied in this paper. This method is based on the principle of AM halftoning, only changed the AM screening lines among the different halftoning images, that is changing the spatial distribution frequency of screen dots, in this way, even in the smaller screening angle (sometimes, even in the same screening angle), we can also achieve the screen dots overlapped images and avoid producing moiré fringe. If this method is combined with the conventional same frequency four-color AM halftoning method, we can realize the more than four-color halftoning without obvious moiré fringe. The frequency conversion AM halftoning configuration method of four-color plus spot colors was proposed in this paper, and non-frequency modulation halftoning high-fidelity printing images were obtained. The results showed that the images achieved the desired effect of high-fidelity printing.

Introduction

More than four-color printing technology is called high-fidelity technology, it is hot issue of international and domestic printing and publishing industry, it relates to multi-color separation, multi-color screening, printing ink and a series of advanced theory and technology.

The basic problem of printed matter color matching is the matching between original color and printed matter target color. In accordance with the principles of color science, only need to make tristimulus values of original pixel equal to tristimulus values of corresponding pixel on printed materials. So, the conventional color separation technique divides original pattern colors into three basic colors, plus black, forms print chromatography range, but in the actual printing process, because of print materials (such as ink and paper etc) performance and conditions of process, if compared with the original natural color, the color gamut space which is reproduced by Y,M,C,K four color is only part of color space closest to the original color, this range(known as color coverage range) is much less than the natural color. In other words, there's a lot of color in nature, it can't show by blending with four inks [1]. In order to more accurately reproduce the original color, we use high purity, other than four-color ink and halftoning replication technique, we can often extend ink color space [2].

One of the aims is to extend the color range by using more than four-color to produce printed materials, it can more realistically reflect the nature. Secondly, because of using printed products of more than four-color separation, the color can't be reproduced by conventional four-color separation technology, so this technology also has special security features. High-fidelity printing technology is more accurately defined as four color plus spot color, four basic color plus spot color, so that make the color closer to the original colorful photo. Color separation and halftoning is the key issue to achieve high-fidelity printing, this paper mainly researched halftoning technology.

The solved key issues of achieving high-fidelity printing

The first problem of achieving high- fidelity printing is to determine what best colors to add four-color.

This problem seems to be no definite answer. Different themes in different printed products, need to focus on the different chromatographic. High- fidelity technology does not necessarily use the R, G, B color, etc, the other spot colors can also be used. Spot color can be from one to more, it can be any color other than four basic colors. If the printed matter is only relatively bright red, we can use cyan, magenta, yellow, red, black five colors to print, it completes one time in the five colors machine. According to different requirements, it will result in different combinations, such as cyan, magenta, yellow, black, green, blue six colors combinations.

According to the general and the actual process requirements, we will have a basic choice to meet the needs of most users. In this regard, different manufacturers (or school) develop their own standards. Pantone company uses C, M, Y, K, blue, green, six colors, Linotype-Hell and Kupper companies use C, M, Y, K, orange, green, purple seven colors system, Scitex company uses C、M、Y、K、R、G、B seven colors. For example of seven colors print method used by Scitex company, the colors of printed products is made of 26 different constitute conditions, including:

(1)Y,M,C,R,G,B,BK;(2)Y+R,Y+G,M+R,M+B,C+G,C+B,Y+BK,M+BK,C+BK,R+BK,G+BK,B+BK;(3)Y+R+BK,Y+G+BK,M+R+BK,M+B|BK,C+G+BK,C+B+BK;(4)W_0.

The second problem of achieving high- fidelity printing is to how to achieve more than four-color separation and halftoning.

When we chose the used color system, the difficulty of color separation is to solve the problem of extracting the spot color outside the four-color, at present, the ready-made high-fidelity color separation software provided by Pantone company can be used directly. This paper mainly researched halftoning problems.

According to the theory of moiré fringe, the AM dot ink overprint angle is less than 30°, it will produce the perceived moiré fringe, this rule limits the halftoning color number is not more than four(there are possible three angles when screen angle interval is 30°, yellow plate is an exception, although the screen of yellow plate and the nearest plate is only 15°, but because the yellow is very bright, produced moiré fringe can't be perceived). So, the conventional halftoning only limit to use CMYK color, any additional fifth Screen will cause significant moiré fringe and

CMYK four-color overprint. There is no angle in FM screen, it can't produce moiré fringe, so, in theory, we can use FM to overprint any number of colors and not worry about moiré fringe. However, the current problem is the process of making FM screen print plate is too difficult, application is extremely difficult. Can we avoid the difficulties of using FM screen technology, use mature and easy FM halftoning technology and achieve more than four-color high-fidelity printing? Before the frequency conversion amplitude modulation proposed in this paper, it seems that there is no better solution. FCAM provides the technical possibility to solve this problem [3].

The third problem of achieving high-fidelity printing is the difficult of platemaking and printing process.

High-fidelity printing usually has to use a more sophisticated screening lines (200lpi or more), or use FM dot which diameter is very small. This puts forward higher requirements of plate burning (or output) and accuracy of printing equipment, in particular the formation of plate xz is more critical. Because film plate burning will inevitably result in the loss of dot, in order to improve the accuracy of platemaking, we use CTP system to directly output plate, this is the best choice for high-fidelity printing platemaking. Furthermore, the FCAM method proposed in this paper also helps to reduce the technological difficulties of platemaking and printing.

Studies on Frequency Conversion Amplitude Modulation

The basic way of new screening method proposed in this paper is as follows: For different halftoning image, use AM screening technology and convert screening lines of different halftoning image (i.e., screening resolution). Halftoning image can be overlapped without moiré with smaller screening angles even with the same angles. Consequently, the problem that AM with same screening lines must use bigger screening angle to avoid the influence of moiré is overcome. The method offers new technology solution to achieve Hi-Fi printing and to solve the screening problems in which screening angles are not convenient to change or there are some special needs.

We defined this method as frequency conversion amplitude modulation[4], FCAM, as it only changes screening lines between different halftoning images according to AM (i.e., spatial distribution frequency of dot is changed).

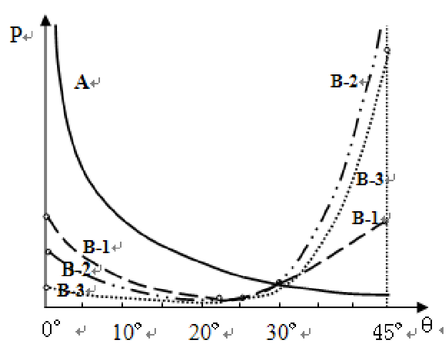

Figure 1. *Variations of moiré of Same and Conversion Frequency*

In figure.1, curve A which is obtained according to common moiré calculation formula denotes that the variation of distance between moirés ($P_{moiré}$) of two screens of 175lpi which are overlapped in the range of 0^0-45^0. Curve B-1,B-2,B-3 which are dependent on experiment data denote the variation of distance between moirés of two screens which are overlapped in the range of 0^0-45^0 when the halftoning frequency difference reaches a certain value between screen and another frequency conversion screen. The screen lines are 150lpi, 133lpi and 120lpi, the screen lines differences are 25lpi, 42lpi and 55lpi separately.

The trend of the moiré strength along with the screening angles variation decreases from infinite to huge, to tremendous then to small to have less interference on visual perception and to the minimum at 45^0 when halftoning images with same screening lines are overlapped (figure.1, Curve A). Generally speaking, moiré strength caused by screen angles whose difference is more than 30^0 is acceptable. Consequently, difference of screening angles should be increased as big as possible in common four-color printing and the screen angles difference of principal color is selected as 30^0 commonly.

Moiré of curve B-3 in figure 1 is not obvious in area of 30^0 which makes up more moiré strength in curve A exactly. Moiré strength of curve B-3 increases in the area of more than 30^0 while it is not obvious in curve A. Consequently, many problems caused by AM can be solved by combining the two curves. Some principles should be complied according to the mechanisms of FCAM as follows:

(1)Avoid overlapping the screens in the area of 45^0 as the maximum strength of moiré of FCAM will emerge at 45^0 (except the situation that the difference of screening resolution is great).

(2)The difference of screening resolution should be appropriate. Firstly, the screening difference means jump of dot frequency and the big difference has more influence on the quality of image reproduction. Secondly, if the difference is beyond special value, darker (i.e., lightness of moiré is verse to that of common moiré) and bigger moiré will emerge at 0^0.

(3) Use one of the most minimum moirés of 20^0-30^0. There is a minimum moiré in the area when overlap all screens of FCAM.

Solution to Achieve Four-Color and Spot Color (Hi-Fi) Printing Using FCAM

It is facilitate to find that harmful moiré will not emerge by combining common AM and FCAM together to overlap halftoning images in more wider range of screening angles according to the variation of Curve A and Curve B in fgure.1 (where A and B have strong complementarities). One of the most important applications is that four-color and spot color, Hi-Fi printing can be achieved.

We can propose several solutions to perform four-color and spot color, Hi-Fi printing according to more experiment results of FCAM [5].

One of the basic prerequisites to avoid moiré is to change screening lines of one halftoning image which inevitably causes the screening lines of another halftoning image increase or decrease. In order to improve the definition of image, dominant tones (i.e., primary tones) should use high screening resolution as far as possible while spot color should use low screening resolution. Another object of increasing screening resolution of dominant tones is to make spot color screening resolution not two low. Screening resolution of 200lpi can be achieved using common four-color printing machine according to present printing equipments and plate making techniques. Screening resolution of 250lpi can be also achieved in the company of good conditions. In our experiment, we selected 200lpi or 225lpi at most in order to decrease operational difficulty of techniques. It would get better reproduction result by selecting 250lpi if techniques condition permits.

Soltuion1: Select 225lpi as the basic screening resolution to achieve six-color printing including four primary colors and two spot colors.

Use screening resolution, 225lpi, to perform four screening angles, Y (0º), C (15º), M (75º) and K (45º), and use two variation frequency screens with solution, 133lpi, as spot color screens. The screening angles of spot color screens are 15^0 and 75^0 (figure.2). In this process, we use the phenomenon that moiré will not emerge when overlap angle is within 0^0-35^0. Two spot color screens are arranged at 15^0 and 75^0 which makes the angle difference with in 0^0-35^0 among the angles of two spot color screens and four screens, Y (0º), C (15º), M (75º) and K(45º). Moiré will not emerge between the two spot color screens in which the angle 60^0 corresponds to 30^0.

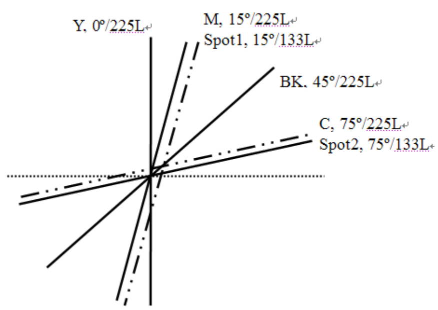

Figure 2. *Arrangement of Frequency & Angle of 6-Color Printing*

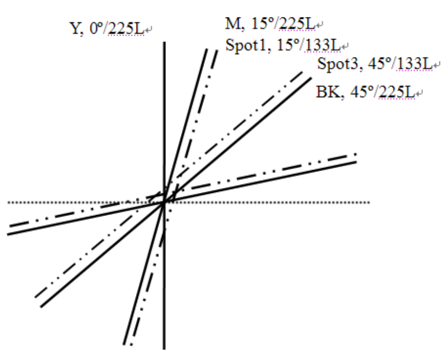

Figure 3. *Arrangement of Frequency & Angle of 7-Color*

Solution2: Select 225lpi as the basic screening resolution to achieve seven-color printing including four primary colors and three spot colors.

Use screening resolution, 225lpi, to perform four screening angles, Y (0º), C (15º), M (75º) and K(45º) and use three variation frequency screens of 133lpi as spot color screens. The screening angles of spot color screens are 15^0, 45^0, and 75^0 (figure.3). Compare with solution1, solution2 has one more screen of 45^0 and others are same as solution1. The angle differences between spot color screen of 45^0 and black screen, cyan screen and magenta screen are 0^0, 30^0 and 30^0, which makes sure moiré will not emerge. The difference between spot color screen of 45^0 and yellow screen is 45^0, which makes weak moiré of 36lpi emerge. Such moiré is not easy to perceive as yellow color is weak. Furthermore, the differences among the three spot color screens are 30^0, 30^0 and 60^0 (i.e., 30^0) respectively, so that moiré will not emerge.

Although there are coincidences in the above arrangements of six-color and seven-color, such perfect and artful arrangements are eyeable.

Test Analysis on Color Gamut Expansion of Hi-Fi Printing

In traditional printing, color tone reproduced by conventional screening technology and common ink accounts for only a small fraction of tone perceived by human eyes or recorded by film as four-color printing restricts the representation gamut of color. While, in Hi-Fi printing, good-enough color is reproduced as spot colors, R, G, and B spot color ink, are used, which expand color gamut of printing. FCAM proposed in this paper offers technical support to achieve Hi-Fi printing in digital halftoning. Color gamut expansion of seven colors, C, M, Y, K, R, G and B can be tested and analyzed as follows[2].

Test Analysis on Color Gamut in CIE1931xyz coordinate

Use SMP100 spectral photometer to measure chromaticity coordinates of six solid colors, Y, M, C, R, G and B, of Hi-Fi printing and four-color printing according to CIE color measurement method (Table 1). Determine position of six solid colors in CIE1931 chromaticity diagram and connect these six points. Then we got the polygons of Hi-Fi printing and four-color printing. These two polygons denoted the gamuts of two printing methods respectively (figure.4).

Table1 Chromaticity Coordinates of Color Patches

	x		y	
	4-color	7-color	4-color	7-color
y	0.4689	0.4769	0.4984	0.5155
r	0.5933	0.6263	0.3375	0.3375
m	0.4740	0.4376	0.2022	0.2022
b	0.2030	0.1700	0.1274	0.1274
c	0.1604	0.1497	0.2531	0.2531
g	0.2468	0.2390	0.6478	0.6478

The area of polygon denotes the number of color tones. The larger the area is, the larger the color gamut is. In figure.4, the gamut of Hi-Fi printing is larger than that of four-color printing obviously, which denotes the gamut of Hi-Fi printing is expanded to represent original color more vividly.

Ink is required to expand the color gamut under the circumstances to guarantee enough lightness of printing production in color printing. Consequently, when select ink, we should select ink of purity and lightness, P_C and Y, appropriately and maximize the product of Pc and Y, Pc·Y. In this way the color having both higher lightness and higher saturation is defined as blossom color. In Hi-Fi printing, we use three spot colors, R, G and B, to replace the secondary color generated by overlapping Y, M and C in traditional color printing. This method improves the color saturation and meets the condition that color approximates to blossom color.

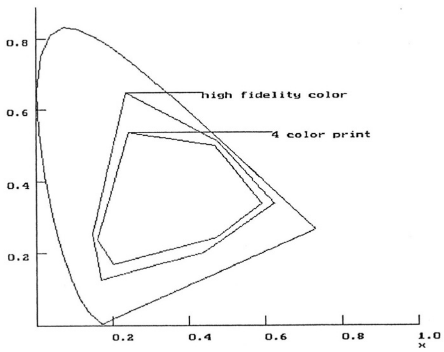

Figure 4. Color Gamut in CIE1931xyz diagram

Test Analysis on Color Gamut in CIE 1976L*a*b* uniform color space

Use SMP100 spectral photometer to measure a*, b* of Y, M, C, R, G and B six colors solid in Hi-Fi printing and a*, b* of Y, M, C, Y+M, Y+C and M+C six colors solid in four-color printing, results are shown in table 2, the color gamut map made in the a,b coordinate system of CIE 1976 L*a*b* color space is shown in figure 5.

Table2 a*,b* of color patches solid

	a*	b*	a*	b*
	4-color	4-color	7-color	7-color
y	-2.98	97.52	-3.05	89.36
m	67.26	-8.05	65.34	-7.93
c	-35.36	-37.04	-34.56	-40.28
r	69.26	41.07	51.85	39.16
g	-51.59	27.65	-37.58	38.18
b	18.80	-37.30	10.33	35.65

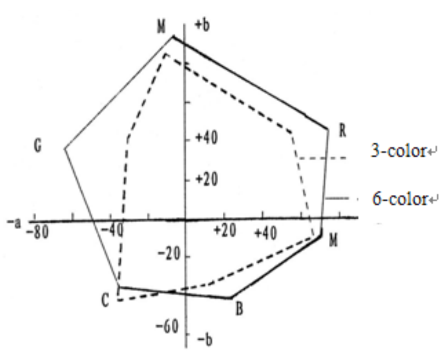

*Figure 5. Comparison of color gamut in CIEL*a*b**

Known from figure 5, compared the color gamut between Hi-Fi printing and four-color printing, the positions of Y, M, C three colors are almost same, while because spot colors R,G,B in Hi-Fi printing are once color, the range of color gamut surpasses the second color Y+M,Y+C,M+C in four-color printing, so The overall color gamut is greater than four-color printing.

Conclusions

Halftoning technology was invented one century ago, people have found two method to eliminate Moire fringe, One method is combination of variation screening angles of AM. The other is irregular frequency modulation screening. Although there are some disadvantages in these two methods, they both are proper and effective by practice. The method of frequency conversion amplitude modulation proposed in this paper is proper by experiments and is innovative in digital halftoning technology field. This method is obviously different from common AM halftoning in the strength and variation laws of moiré. We studied the application of FCAM in four-color+spot color Hi-Fi printing by summarizing related laws and many experiments. And we used CTP to output plate and made printing proofs according to 6-color solution and 7-color solution based on FCAM proposed in this paper. The results showed that the design proposal met the demands for Hi-Fi printing.

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