Improved Color Consistency in Halftone Image by "VR Screen" Technology used for FIRST PROOF™

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Abstract

We developed a new screening method named "VR screen" for thermal halftone imaging system especially for "Thin-layer Thermal Transfer (3T)" system. The color variance and moiré stripes were successfully avoided by varying dot pitch in sub- and main-scanning directions by color in special ratios. We have developed an algorithm to convert RIP data to dot-layout data of this method and was implemented to achieve good color consistency and uniformity. The gray color variance problem is general in halftone imaging systems that employ print head of lower resolution and can be solved by this method.

Introduction

In recent years, the need for digital color proofer (DDCP) is growing. The finish of DDCP is desired to be similar to press-prints in the color reproduction, appearance and the feel of paper.

We realized FirstProof™ system for DDCP under reasonable cost that can print the halftone image on stock paper. First Proof uses the modified LOUVER method[1] to modulate the size of halftone dots by using a widely-used low-cost 300dpi thermal head and the "thin-layer thermal transfer (3T)" method to produce high quality dots as we report in a separate paper[2] in this conference

There are three trends in the method for realizing DDCP shown in Table 1. Each system has some demerits. The laser thermal transfer system is expensive. The dye-sublimation system does not produce dots which is desirable to verify the image data in highlight part of the image with a magnifying glass. In the ink-jet system, the dither pattern would be conspicuous and the letters tend to spread.

Table 1. DDCP System comparison.

System	Laser TT	Dye-Sub.	Ink Jet	3T FirstProof
Gradation	dot size	density	dot number	dot size (Louver)
Screening	press screen	continuous tone	dither	VR screen
Low-cost	**poor**	good	good	good
Verifiability of dots	good	**none**	good	good
Conspicuous Dither	good	good	**poor**	good
Letters quality	excellent	good	**poor**	good
Stock paper	good	**poor**	poor	good

We report a new screening method "VR screen", which is a key technology of FirstProof system. We explain the color variance problem to be solved by "VR screen", the concept of out solution, the possible and preferred configurations, and the final implementation.

The Color Variance Problem

A straightforward application of halftone screening using thermal head in 3T system would result in non-uniform color reproduction, like a rainbow, in gray images with four colors. This situation is visually described in Fig. 1. When the dot-layouts of K, C, M and Y are the same and completely overlapped, the appearance is neutral gray (left bottom, Fig. 1). But if the overlapping is incomplete as shown at the right bottom in Fig. 1 for example, a portion of each magenta dot comes out from behind the black dot resulting in recognizable magenta appearance. This phenomenon, "color variance", is a major problem to be solved for the system to be used in DDCP.

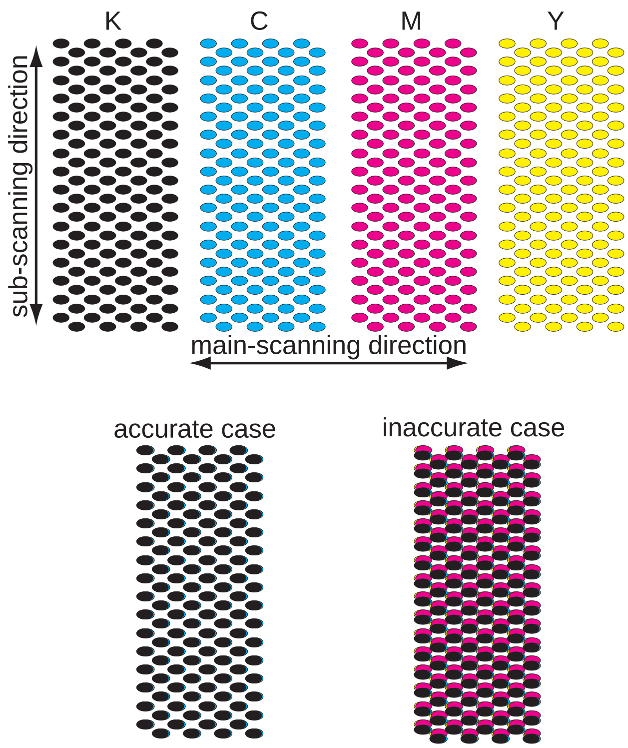

Fig.1 Normal dot layout produce the color variance depending on the registration accuracy.

Theoretical consideration lead us to conclude, however, that this problem is general and fundamental when dot-based halftone screening is attempted using any print head devices of limited resolution. In other words, the ink-jet and wax-transfer printing systems should suffer from the same problem by principle. It is caused by the fact that the screen angle of the four colors have the same orthogonal nature. It induces "color variance" sensitively influenced by the registration. The laser system alone among them is free from this problem because it uses the screen angle method, as in the conventional press print system, due to its sufficiently higher resolution compared with the screen resolution. In this method the ratio of the dot overlapping is always constant approximately 50%, no matter how the registration is deviated.

Policy to Avoid the Color Variance

Such printers have the following mechanical constraints;

(1) the pitch of dot layout is fixed at 85µm in the main-scanning direction but continuous in the sub-scanning direction, and

(2) the registration accuracy in the main-scanning direction is better than that in the sub-scanning direction.

We, accordingly, made a following policy, i.e., to devise a such dot layout that dot layouts of all the colors do not overlap regularly with one another to simulate the screen angle method by making full use of mechanical accuracy in the main-scanning direction and freedom in the sub-scanning direction.

Screening Method

We derived some dot layouts or screenings from the policy above. We evaluated performance and implementability for each method.

Random Dot Layout

First we tried to randomize the dot layout along the sub-scanning direction as shown in Fig. 2. The color variance is better but this method is not sufficient, because the image gave the sandy or noisy appearance and, furthermore, made the gradation control algorithm too complicated to implement.

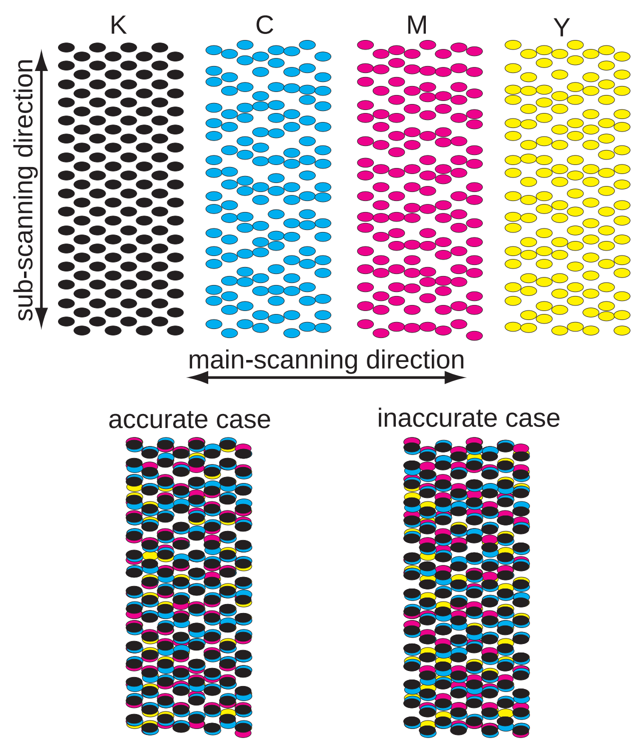

Fig.2 Random dot layout avoids color variance but seems sandy.

Varied Resolution in Sub-scanning Direction

Secondly, we experimented a method to vary the ratios of the dot pitches along the sub-scanning direction among all colors. As the result we succeeded to avoid the color variance but horizontally striped patterns were observed as shown in Fig. 3. These patterns are equivalent to so-called screen moiré or rosette patterns.

The pitch of the horizontal stripe is the least common multiple (LCM) of the pitches of each color in sub-scanning direction. A similar attempt using three colors has been reported[3], hitherto, wherein the pitch ratios were selected 1:2:2 so that LCM of three colors became the minimum value at the sacrifice of margin for the color variance .

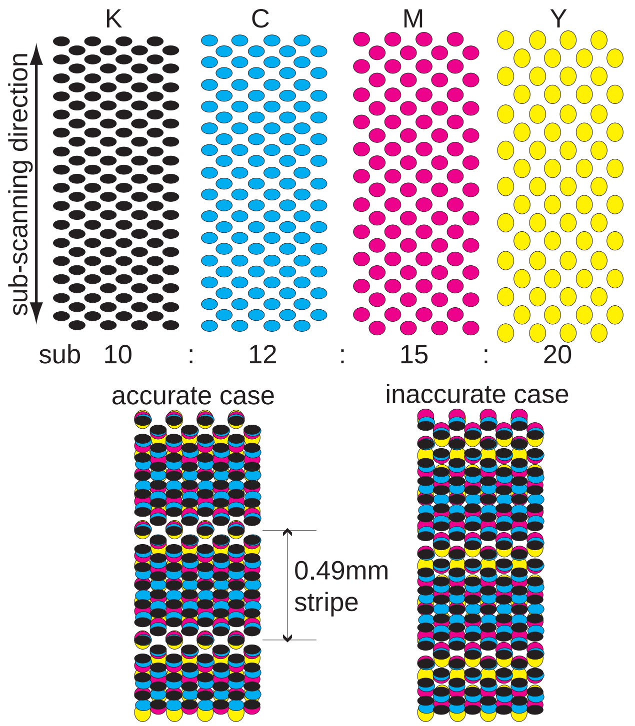

Fig. 3 Varied resolution in sub-scanning direction can avoid color variance but has unacceptable conspicuous horizontal stripe.

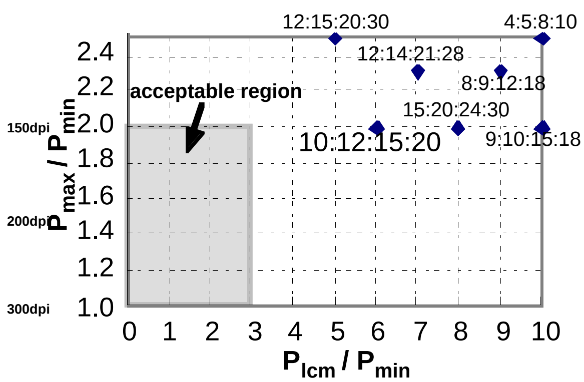

Fig. 4 Calculated results of maximum and LCM for 4 integers. The best combinations are 10:12:15:20.

Also in the case of four colors, it would be effective to make the horizontal stripe pitch to minimize less than 0.2mm. We thus studied the combination of the dot pitches. The constrains are;

$P_{lcm} \leq 0.2$mm, i.e. $P_{lcm}/P_{min} \leq 2.35$ at P_{min}=85μm;

$P_{max}/P_{min} \leq 2$, ≤ 1.5 is preferred;

P_{max} , P_{min} : maximum , minimum dot pitch;

P_{lcm} : LCM of dot pitches for all colors.

The larger P_{max} corresponds to the lower image resolution and the more power to record. The calculated results are shown in Fig. 4. The best combination of dot pitches is 10:12:15:20. But P_{lcm}/P_{min}=6 (P_{lcm}=0.49mm) is not enough to reduce the horizontal stripe, so that this measure could not realize our object either.

"VR Screen"

To make the stripe less conspicuous, we devised a method for making the horizontal stripe intermittent even if P_{lcm}>0.2mm. It is found, as the result, that the problem of the image quality due to the horizontal stripes can be practically solved, by selecting the combination of 1:2:1:2 as the pitches of each color along the main-scanning direction shown in Fig. 5. The ratio of pitches for each color is;

K:C:M:Y=10:12:15:20 in sub-scanning direction;

K:C:M:Y=1:2:1:2 in main-scanning direction.

K is applied to the minimum pitch for the letter quality. Y is applied to the maximum pitch because Y dot is least conspicuous for eye sensitivity. The parameter are P_{lcm}/P_{min}=6 and P_{max}/P_{min}=2.

As described above, the color variance can be avoided by selecting a particular combination of the ratios of the dot pitches of each color, in sub-scanning and main-scanning directions. We named this screening method "VR screen" (varied resolution screen).

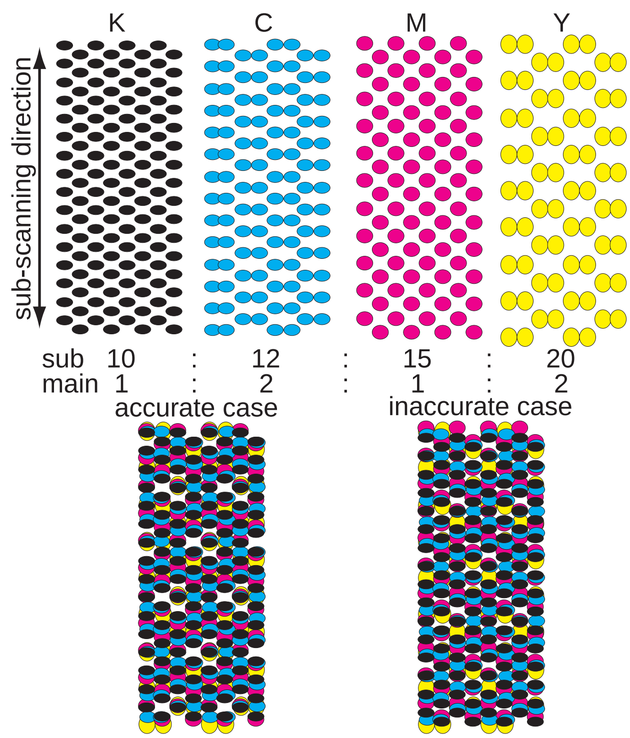

Fig. 5 VR Screen avoids the color variance and the horizontal stripe. The layout in main-scanning direction is devised.

Modified "VR Screen"

We have an acceptable problem of "VR screen" that $P_{max}/P_{min} = 2$ would require so large a recording energy for the head. We can modify "VR screen" to reduce P_{max}/P_{min}. In above description, the dot pitches of all colors were varied relative to each other. However, there are some cases where a modification changing the pitches of only three colors is possible with resulting similar effect.

In an example, we selected the pitch along the sub-scanning direction of Y, of which the color variance is the least recognizable, to be the same as that of K. The ratio is;

K:C:M:Y=10:12:15:10 in sub-scanning direction;

K:C:M:Y=1:2:1:2 in main-scanning direction.

Thus the maximum dot pitch can be reduced to P_{max}/P_{min}=1.5 shown in Fig. 6, so that the maximum recording power to can be reduced. We can select any ratios shown in Fig. 6. This modified VR screen shown in Fig. 7 is applied to "FIRST PROOF" system now.

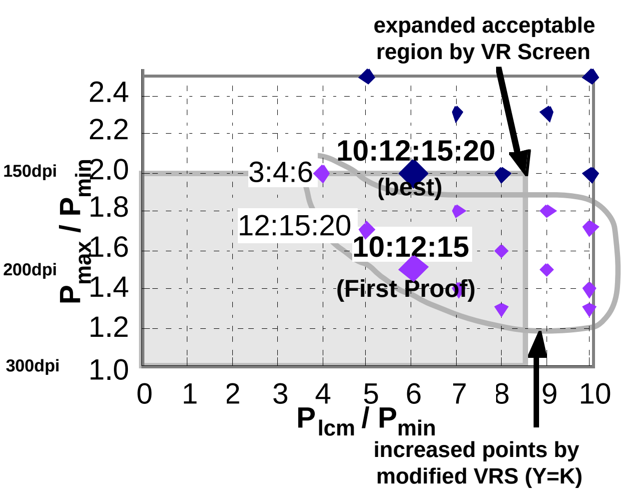

Fig. 6 Calculated results of maximum and LCM of 3 integers are added to that of 4 integers. The ideal rates are 10:12:15:20 (6,2), 10:12:15 (6,1.5), 12:15:20 (5,1.7) and 3:4:6 (4,2). The acceptable rates are 15:20:24:30 (8,2), 21:24:28:42 (8,2), 35:40:56:70 (8,2), 30:35:42 (7,1.4), 21:24:28 (8,1.3), 12:14:21 (7,1.8), 15:20:24 (8,1.6) and 35:40:56 (8,1.6). [remarks: rate (P_{lcm}/P_{min}, P_{max}/P_{min})]

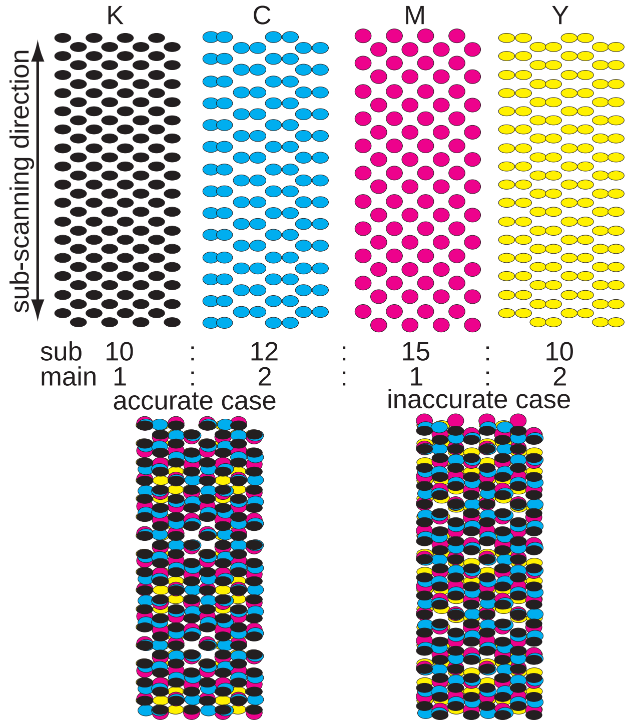

Fig. 7 Modified VR Screen to reduce the maximum pitch from $2P_{min}$ to $1.5P_{min}$. This is applied to FIRST PROOF.

Implementation of VR Screen

We devised a method to put "VR screen" into practice by modifying a ordinary dye-sublimation thermal transfer printer.

The driver circuit is adjustable the strobe timing for the gradation control. It is also possible to control the continuous sheet conveyance to the sub-scanning direction. By operating the strobe with predetermined timing during continuously conveying the paper, any dot pitch can be obtained. Thus the control of "VR screen" becomes possible by the procedure as shown in the Fig. 8.

(a) The original data produced by general RIP for dye-sublimation has the same resolution for each color. (b) The special circuit converts the resolution in sub-scanning direction twice of the dot pitch of "VR screen" for each color. (c) And it masks the data by number corresponding to the dot pitch in main-scanning direction. The head controller send the strobe signal corresponding to each twice resolution. These process is calculated in real time during printing so that printing speed is same as that of dye-sublimation. The example of system configuration is shown in Fig. 9.

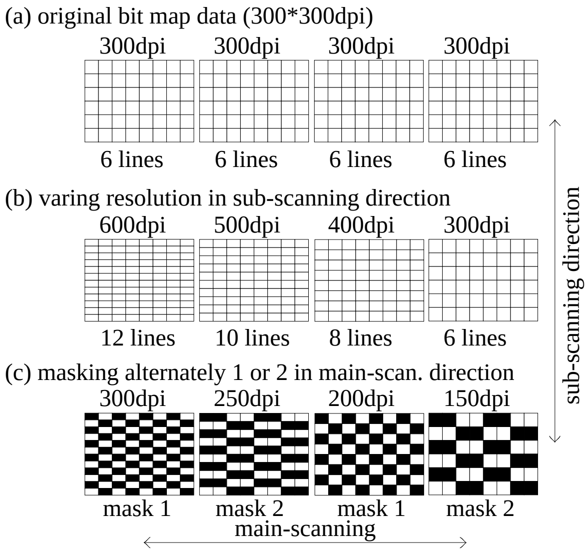

Fig. 8 Procedure to convert the original bit map data of 300 dpi to each resolution data for VR Screen.

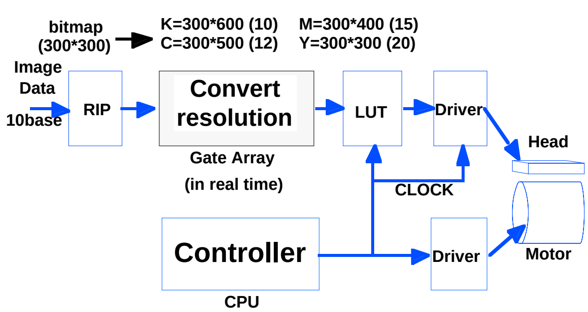

Fig. 9 Implementation to present dye-sublimation printer to add a circuit to convert resolution and to modify the controller software

Generality of "VR Screen"

"VR screen" technology can be utilized generally for the dot-based halftone printers not restricted only for thermal transfer system. "VR screen" is applicable to color ink-jet printer, color thermal printer, color electrostatic printer, etc. "VR screen" will improve the color consistency and uniformity to keep the tone modification and image smoothness of these low-resolution color printers by principle.

Conclusion

We developed "VR screen" method wherein the dot pitch in the sub-scanning direction and that in the main-scanning direction are varied by color in special ratio so that we can avoid color variance without moiré stripes. The problem of the color variance has been solved by use of "VR screen" to realize the low-cost halftone imaging system wherein the image is similar to that of the expensive high-resolution system, in spite of using a low-resolution 300dpi head. "VR screen" improves the color consistency of four color prints.

References

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3. Y.Sonoda, K.Yamakawa, F.Inui, H.Kokubo, H.Saito, T.Miyazaki, M.Sato, `The effects of a pixel layout on the quality of halftone images produced by "LOUVER"', Proceedings of Non-Impact Printing Technologies / Japan Hard Copy '93, page 342