Development of an algorithm for separating halftone dots with removing the effect of optical dot gain

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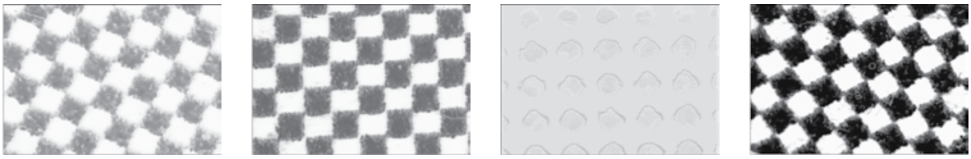
ABSTRACT

Color and tone in printed images are generally controlled by the area modulation of halftone dots. In actual printing processes, however, it is not easy to form a specified dot area because of errors due to the optical dot gains. The optical dot gain is a phenomenon of that in the effective area due to light scattering in paper. Therefore, measurement of an accurate dot area is important for control of printing process and analysis of printed images. In this study, we modeled the edge part of the halftone dot with optical dot gain, and developed a new algorithm to calculate the best threshold to make to binary. And we developed a new algorithm for separating two-color halftone dots with removing the effect of optical dot gain to evaluate the quality of printings using measurements of the halftone dot area. And we proposed a new measurement method of using the transmitted light.

Keywords: Printing, halftone dot, optical dot gain

INTRODUCTION

Color and tone in printed images are generally controlled by the area modulation of halftone dots. In actual printing processes, however, it is not easy to form a specified dot area because of errors due to the mechanical and optical dot gains. The mechanical dot gain is a phenomenon of an increase in the ink area for ink extending, and the optical dot gain is that in the effective ink area due to light scattering in paper tissue structure. Therefore, measurement of an accurate dot area is important for control of printing process and analysis of printed images. In the previous study, we developed the algorithm for separating four-color halftone dots (Cyan (C), Magenta (M), Yellow (Y) and Black (K) shown in Fig.1) to evaluate the quality of printings using measurements of the halftone dot area (Azeoka et al., 2007). However, the effect of optical dot gain was not considered in this algorithm. Therefore, we were not able to measure an accurate dot area of only ink. In this study, we developed a new algorithm for separating two-color halftone dots with removing the effect of optical dot gain.



Cyan (C) Magenta (M) Yellow (Y) Black (K)

Figure 1. Four-color halftone dots.

MEASURING SYSTEM AND SAMPLE PRINTINGS

Figure 2 illustrates a measuring system using a microscope, which consists of a 3-CCD camera attached to a microscope, halogen lamps, video controller, and PC. The expanded images of a printing are taken into PC after adjusting the white balance at the video controller. The magnification of an optical system is 10X. As a sample of printings for experiments, we used Japan Color, color reproduction printings 2001 (ISO12647) that was known as the standard printing sample, as shown in Fig.3.

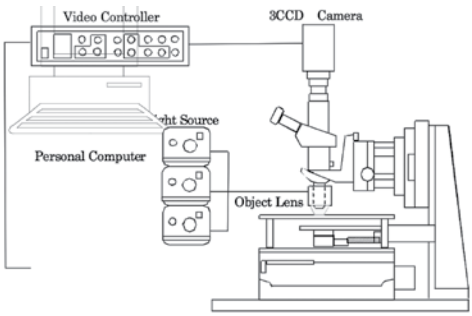


Figure 2. Measuring system.

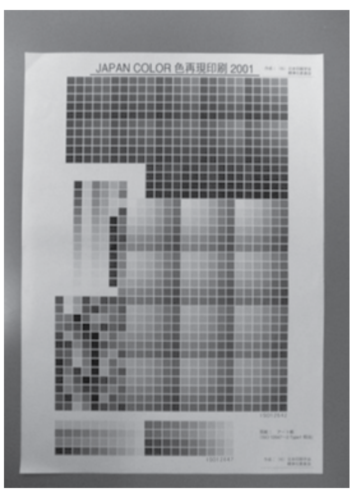


Figure 3. Japan Color, color reproduction printings 2011 (ISO12647).

SEPARATION PRINCIPLE OF OPTICAL DOT GAIN

Figure 4 illustrates an edge model of halftone dots in which ink is ideally adhered to paper with uniform illuminating light. In this case, as shown in Fig.5, the reflected light intensity distribution observed by the measuring system is assumed to be the Gaussian function in the edge due to the effect of light scattering in paper. Therefore, it is well understood that the flection point of the reflected light intensity distribution gives the edge position of a halftone dot and, thus, the effect of optical dot gain can be removed (Yuasa and Mishina, 2006).

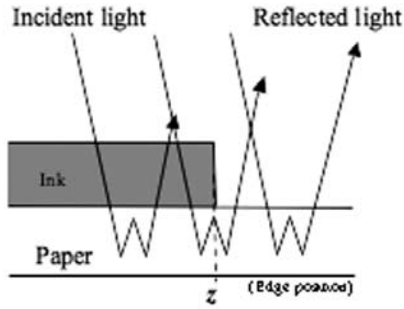


Figure 4. Halftone dot edge model.

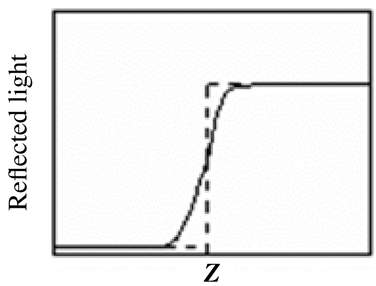
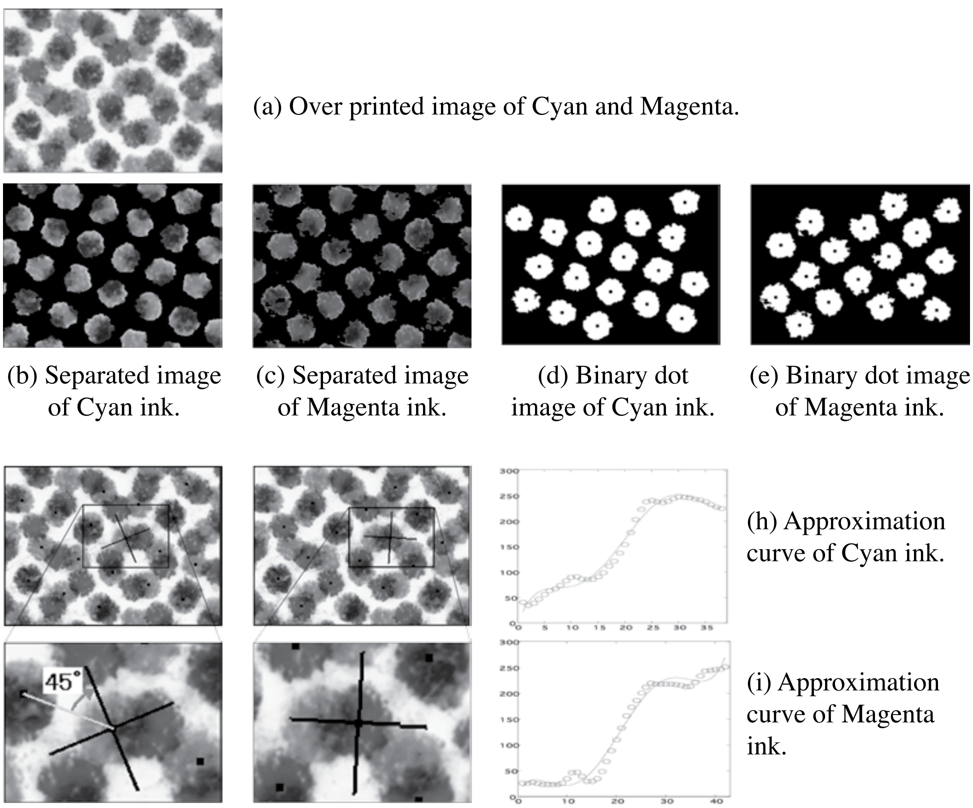


Figure 5. Reflected light intensity distribution.

In an algorithm developed in this study, the separated image of each ink is first obtained from the over-printed image by the conventional algorithm for separating two-color halftone dots, as shown in Fig.6 (Kakumoto et al., 2009). Figure 6 (b) shows the separated image of Cyan obtained from over-printed image of Cyan and Magenta shown in Fig.6 (a). The center of gravity of each halftone dot shown in Fig.6 (d) is secondly calculated from the separated image shown in Fig.6 (b). The calculated center of gravity is next applied to the over-printed image, and each of four straight lines shown in Fig.6 (f) is derived based on drawing a line that leads from the center of gravity of one halftone dot to the nearest center of gravity of another halftone dot. Further, the radiance variation of the complementary element of ink color is obtained from Red (R), Green (G), and Blue (B) elements of the pixel that composes the straight line, and a third-order approximation curve shown in Fig.6 (h) is calculated by the method of least squares.

Finally, the value of the flection point is calculated. In the same way as above that of other color halftone dots is obtained, and the mean value of all flection points is assigned as a threshold that can be used for the edge without the optical dot-gain effect. On the other hand, it is difficult to obtain the center of gravity of each halftone dot in the image with high coverage, because halftone dots of two color inks are connected mutually as shown in Fig.7 (a). In this case, the radiance was reversed, and the threshold was calculated for the center of gravity of each paper area shown in Fig.7 (b) that can be regarded as if it were the halftone dot. Moreover, both connected halftone dots and independent halftone dots exist together in one image shown in Fig.8 (a) when the set coverage is 50% and 60%. In this case, the line thinning was performed until connected halftone dots were separated each other, because it was difficult to obtain both the center of gravity of each halftone dot and the center of gravity of each paper area, as shown in Fig.8 (b). Afterward, the center of gravity of each separated halftone dot is calculated, and the threshold is obtained.



(a) Over printed image of Cyan and Magenta.

(b) Separated image of Cyan ink.

(c) Separated image of Magenta ink.

(d) Binary dot image of Cyan ink.

(e) Binary dot image of Magenta ink.

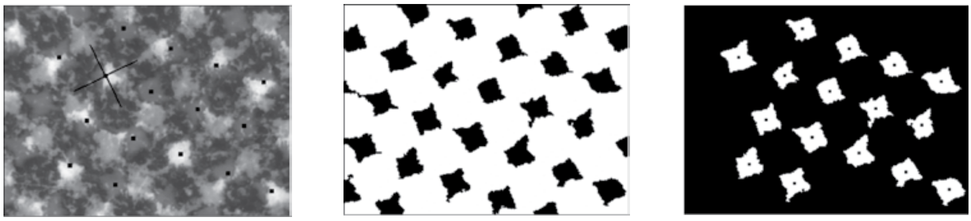
(f) Center of gravity of Cyan ink.

(g) Center of gravity of Magenta ink.

(h) Approximation curve of Cyan ink.

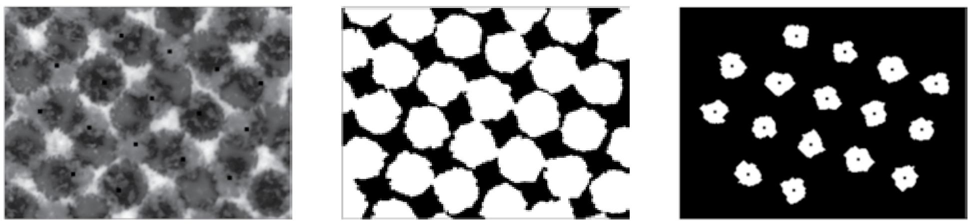
(i) Approximation curve of Magenta ink.

Figure 6. Over-printed image of Cyan and Magenta (set coverage is 40% each).



(a) Separated binary image of Cyan ink. (b) Reverased binary image of Cyan ink.

Figure 7. Over-printed image of Cyan and Magenta (set coverage is 70% each).



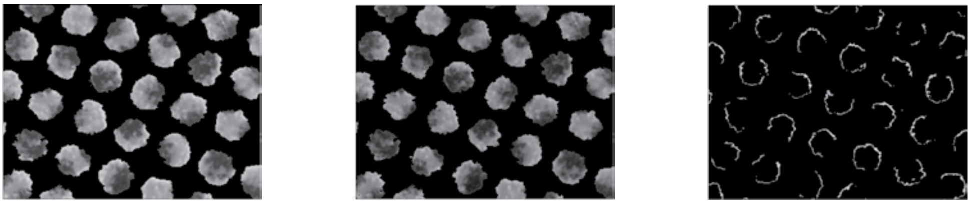
(a) Separated binary image of Cyan ink. (b) Thin-lined binary image of Cyan ink.

Figure 8. Over-printed image of Cyan and Magenta (set coverage is 60% each).

RESULTS AND DISCUSSION

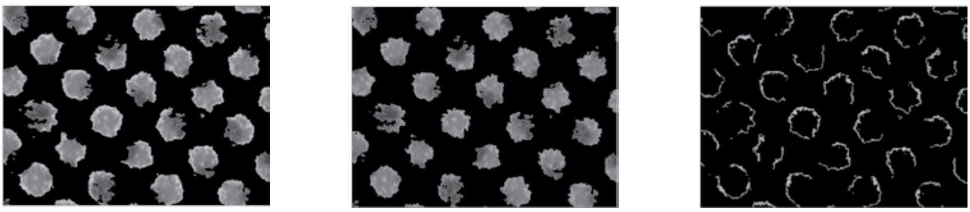
Figure 9 shows resultant images in the case of Cyan ink. Image (a) contains the optical dot gain since it was obtained by the conventional algorithm for separating four-color halftone dots, and image (b) shows no optical dot gain since it was obtained by the proposed algorithm. As a result, a more detailed edge of halftone dot is clearly seen in (b) than that in (a). Image (c) shows a result obtained by subtracting image (b) from image (a). This image is considered to give only the optical dot gain. Figure 10 shows resultant images in the case of Magenta ink, which demonstrate also reasonable optical dot gain pattern.

Figure 11 shows the resultant coverage of optical dot gain and halftone dots for each set coverage in the over-printed image of Cyan and Magenta. As shown in Fig.11 (a), we could confirm that the effect of optical dot gain was large in the set coverage about 60% that has a long circumference length of halftone dots. The effect was small in the low coverage due to small halftone dots or in the high coverage due to the connected halftone dots. This is because the boundary line of ink and paper is short. However, such a tendency is not seen in Fig.11 (b), and the effect of optical dot gain is found to be large in the high coverage. The circumference length of Magenta ink becomes longer in the high coverage because Magenta ink is printed after Cyan ink is done, and the adhesion of Magenta ink printed on Cyan ink is degraded usually.



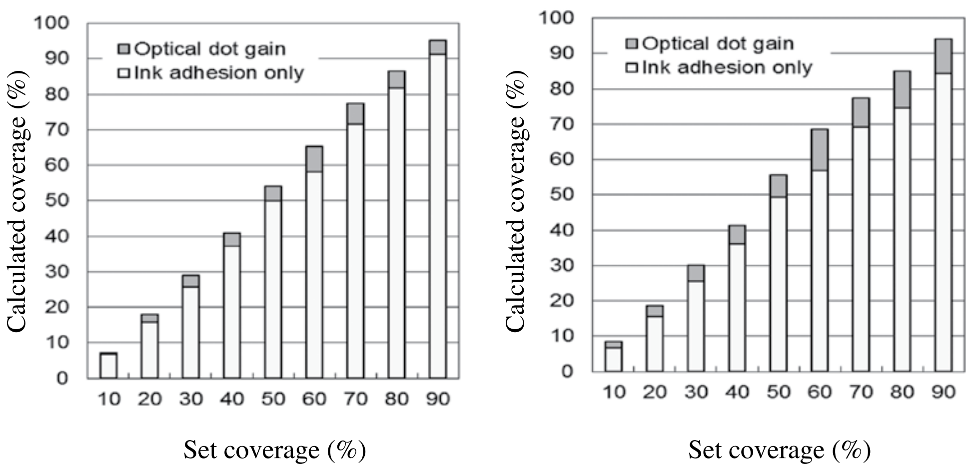
(a) Conventional method. (b) Proposed method. (c) Optical dot gain image.

Figure 9. Resultant images of Cyan ink.



(a) Conventional method. (b) Proposed method. (c) Optical dot gain image.

Figure 10. Resultant images of Magenta ink.



(a) Cyan (b) Magenta

Figure 11. Coverage of the optical dot gain and halftone dots. (Over-printed image of Cyan and Magenta)

CONCLUSION

We developed the measurement algorithm for halftone dot coverage that removed the effect of optical dot gain in two-color printed halftone dot images. It was realized to separate the optical dot gain and the real ink area. Moreover, it became possible to evaluate quantitatively the effect of optical dot gain at each coverage and the actual states of ink adhesion. Our future work is to develop an algorithm for three-color and four-color over-printed images and to construct other separation algorithms to examine the adequacy of the present algorithm.

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