Characteristics of the Shapes of Printed Dots

Shigeru Kitakubo, Yasushi Hoshino, Shi-Biao Xu
Nippon Institute of Technology
Miyashiro, Saitama, Japan

Abstract

In this paper, we observe the shape of printed dots or clusters of dots, and consider the factors which affects the uniformity of dot size. It is important to discuss the shape of printed dots because dispersed dots and clustered dots produce the mid-tone images in the halftoning process. To investigate the halftoning of high density area of an image, we also observe 'white clusters,' which are the areas surrounded by dots.

Introduction

Algorithms of converting a continuous-tone image into a binary high quality image are important in non-impact printing field. A great number of digital halftoning algorithms have been presented. Recently, FM screening has been extensively studied. We proposed some new algorithms which includes both AM and FM screening method in 1995, and discussed the relation between the resolution of printer and the quality of output image in 1996. We analyzed the error which will be caused by binarization process in 1997. In 1998 and 1999 we discussed the relationship between the minimum dot size and the print quality considering the human visual sensitivity. Through these results we recognized the importance of halftone screening method, which is one of the most widely-used binarization methods in printing and publishing industry. In 2000 and 2001 we discussed the stability of the shape of minimum dots and the merits of clustered dots.

In this paper we show some experimental results and their analyses with respect to the relationship between the size and the stability of clusters. This time we analyze not only black clusters which are normal clusters of printed dots, but also white clusters which are the areas surrounded by dots. We hope this study leads to the characterization of the variety of the shapes of dots printed by laser printers.

In recent non-impact printing field, most printers output small dots to form each character or image. By arranging the location of dots, they can express every data such as characters, symbols, figures, and even continuous-tone pictures. We can say there are two groups of factors that affect print quality. One consists of the factors that have relation to printing software, for example, the algorithm of arranging the location of dots. The other consists of the factors that have relation to printing hardware, for example, dot size, accuracy of print position, and density of dots.

As mentioned above, two halftoning methods are widely used, and dispersed dots are mainly used in FM screening , while clustered dots plays an important role in AM screening method. Each method has its own merit. When we discuss the application of these methods, dot size and its uniformity are important factors to be considered.

In the follwing, we define a cluster and describe the way to observe clusters. Then we show the result of our experiment and discuss it. Finally we summarize the discussion.

Experimental

First we create 12 sample digital images by using an image processing software and then print them out. The digital images are created by using image processing software. We call these images (B1) – (B4), (W1) – (W4), (C1) – (C4), each consists of the following dot patterns:

(b1) a single dot,
(b2) a cluster of 2x2=4 dots,
(b3) a cluster of 3x3=9 dots,
(b4) a cluster of 4x4=16 dots,
(w1) a 16 dots by 16 dots square without a single dot in the center,
(w2) a 16 dots by 16 dots square without a cluster of 2x2=4 dots in the center,
(w3) a 16 dots by 16 dots square without a cluster of 3x3=9 dots in the center,
(w4) a 16 dots by 16 dots square without a cluster of 4x4=16 dots in the center,
(c1) a 16x16 checker pattern,
(c2) an 8x8 checker pattern in a 16 dots by 16 dots square ,
(c3) a 5x5 checker pattern in a 15 dots by 15 dots square, and
(c4) a 4x4 checker pattern in a 16 dots by 16 dots square,

where there are 128 single dots in (c1), 32 clusters of 2x2=4 dots in (c2), 12 clusters of 3x3=9 dots in (c3), and 8 clusters of 4x4=16 dots in (c4).

To make each of the images (B1), (B2), .., (C4), we place 100 same patterns in an area of A4 size. For example, we place one hundered clusters of 4x4=16 dots (b4) at various position of an A4 size area to make (B4).

We print the sample digital images on plain papers by using a 300 dpi laser printer which is a widely used printer for personal usage. After that each printed image is scanned and transfered into a computer by a scanner at the resolution of 1600 dpi. Then the shapes of dots are observed and size and brightness are measured by an image analyzing software.

Results and Discussion

We show some sample digital images and scanned images of the printed images of them in Fig. 1. The values of average area of each scanned cluster, the values of standard deviation, the values of coefficient of variation, and the values of area of each sample cluster are shown in Table 1.

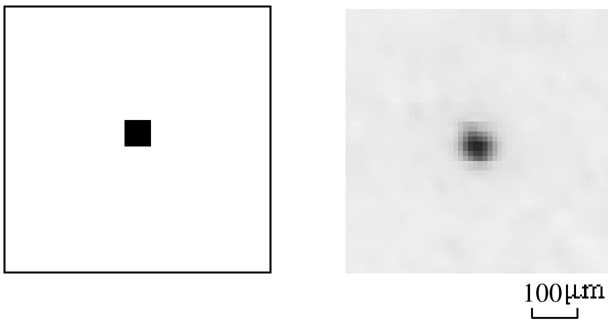

Figure 1(A). Sample (left) and scanned images of the dot pattern (b1).

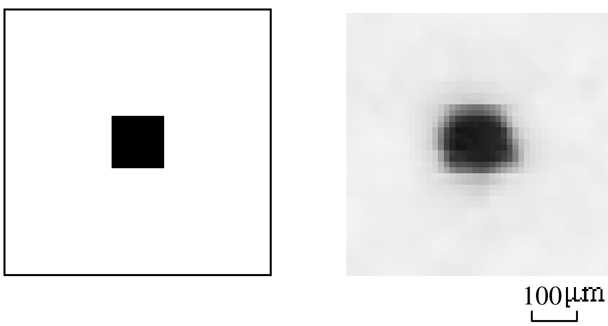

Figure 1(B). Sample (left) and scanned images of the dot pattern (b2).

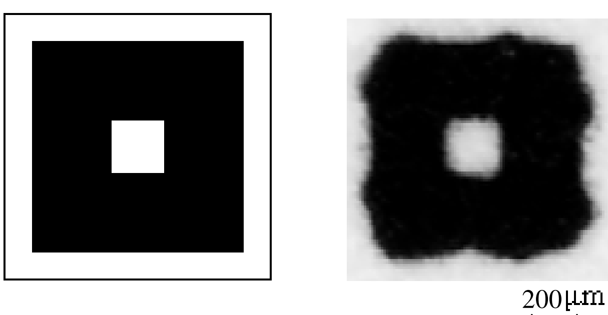

Figure 1(C). Sample (left) and scanned images of the dot pattern (w4).

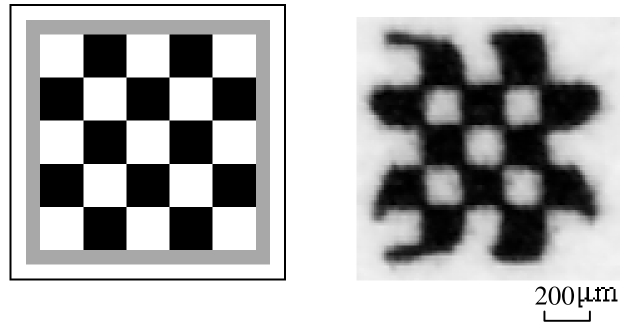

Figure 1(D). Sample (left) and scanned images of the dot pattern (c3).

Table 1. Observation results of 12 patterns of sample images; average area, standard deviation of 100 samples, coefficient of variation of area, and the the area of each sample cluster.

Image	Average Area of Printed Cluster (μm^2)	Standard Deviat'n (μm^2)	Coeff. of Variat'n of Area	Area of a Sample Cluster (μm^2)
B1	6200	1202	0.19387	7168
B2	34350	2613	0.07607	28674
B3	76810	3768	0.04906	64516
B4	128890	5289	0.04103	114695
W1	0	-	-	7168
W2	11076	2931	0.26463	28674
W3	42688	4150	0.09722	64516
W4	89241	5444	0.06100	114695
C1	1960046	34682	0.01769	1083295
C2	1729275	67170	0.03884	1083295
C3	1208465	58954	0.04878	939926
C4	1272111	37402	0.02940	1083295

From the results above we noticed several characteristics of printed dots. Here we discuss three of them listed below:

(i) Compared to the corresponding sample cluster, most black clusters and checker patterns have larger value and all white clusters have smaller value.

(ii) As the cluster size increases, the coeffficient of variation of area decreases, which means the stability of the shapes of clusters will increase.

(iii) A printed single black dot is smaller than a sample dot, and a cluster of more than 4 black dots is larger, which means there is a certain size where the size of both printed and sample clusters coincidents.

As for (i), it could be said from Fig. 2 that some of the toner particles, or minimum dos, tend to expand or disperesed around the accurate printing position. This can explain why white clusters are 'invaded' by black dots as in Fig. 1(C) and Fig. 1(D).

As for (ii), it could be said from observations that the cluster size varies because the shape of edge is unstable. This may happen because the boundary of images in the development and transfer process inside printers tends to be affected by the noise from outside. If the noise increases in proportion to the length of boundary of the cluster per the cluster size, unstability of the shape of the cluster will be weakened as the cluster size increases, and Fig. 3 shows this trend. We can expect the coefficient of variation of area will converge to a certain value less than 0.05.

As for (iii), it could be said from observations of Fig. 4 that a cluster of 2 dots has almost the same value of area as a digital sample cluster of 2 dots does. Since we are still pursuing what causes this phenomenon, we describe two factors that we think of; (a) there is a certain size of image at that toner particles form sufficient image on the surface of a photoreceptor, (b) some toner particles disperse on the paper or peel off from the paper when the cluster size is small. When we discuss (a), we need to consider the relation between the size of images and the thickness of photoreceptive devices.

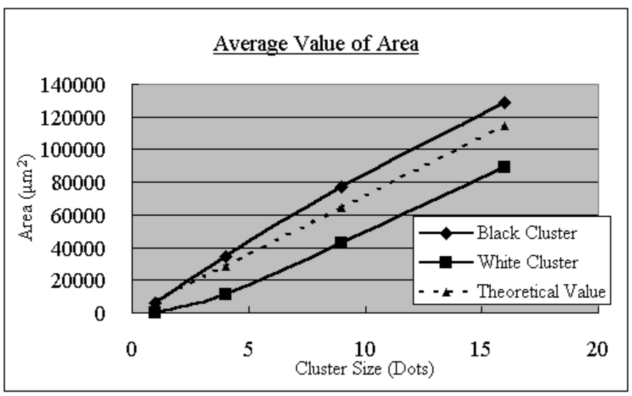

Figure 2. Average Value of Printed Area

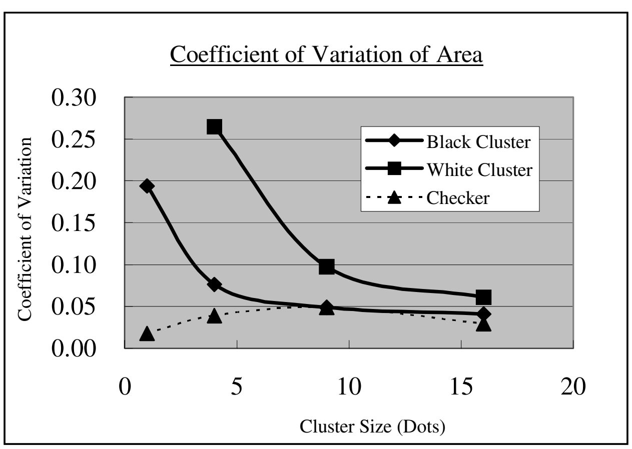

Figure 3. Coefficient of Variation of Area

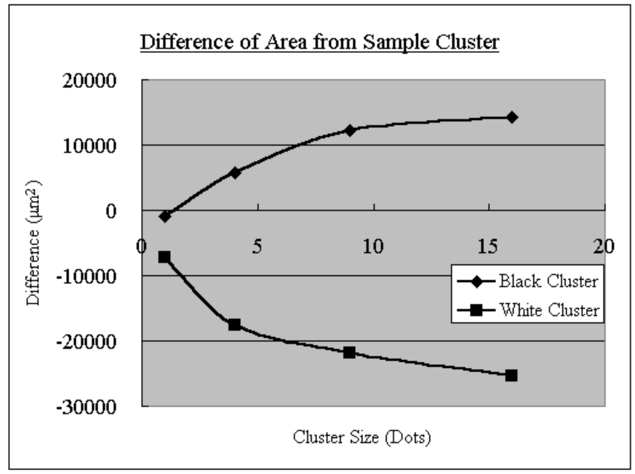

Figure 4. Difference of the Value of Printed Area from that of Sample Area

Conclusion

Shapes and sizes of printed dots were observed from the viewpoint of investigating the variation of printed dots. In addition to the former experiment, we used image analyzing software to get more accurate data. Images printed by a laser printer and scanned by a scanner were used. As the result of our experiment it was clear that the uniformity of the shape increased in proportion to the cluster size. On the other hand, interesting result arose about a small dot and printed size. These results will supply some fundamental data to decide which halftoning method we should choose, dot clustering type or dot dispersing type. Moreover, it can be expected these data leads to the improvement of mage quality of printers.

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Biography

Kitakubo Shigeru is Assistant Professor of Nippon Institute of Technology. He received his Bs., Ms. and Dr. degrees in Science from Tokyo Institute of Technology in 1986, 1988, and 1992, respectively. In 1993 he got a position at Nippon Institute of Technology. He participates in every NIP conferences since 1995. He is now interested in digital processing theory.