Effect of Dot Clustering on Stability of Printed Image

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Abstract

In this paper we compare several patterns of clustered dots printed by an ink jet or an electrophotographic printers. 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. While a larger cluster is more stable in size and shape, some white areas surronded by certain patterns of clusters are affected by those clusters.

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 is a further study of the results in 2002, which describes the characteristics of not only black clusters, but also white clusters. We hope this study leads to the characterization of the variety of the shapes of dots printed by inkjet or 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

We used 12 sample digital images which we made in 2002. We call them B1, .., B4, W1, .., W4, C1, .., and C4, respectively. We describe the shape of each image in Table 1. Every cluster in each sample image consists of a perfect square.

We then print the sample digital images on plain papers by using a 720 dpi inkjet printer and a 300 dpi laser printer which are widely used for personal usage. After that each printed image is scanned and transferred into a computer by a scanner at the resolution of 1600 dpi. We call those scanned images PB1, .., PB4, PW1, .., PW4, PC1, .., and PC4, respectively. Then the shapes of dots are observed and size and brightness are measured by an image analyzing software.

We show some sample images in Fig.1(A)-(C).

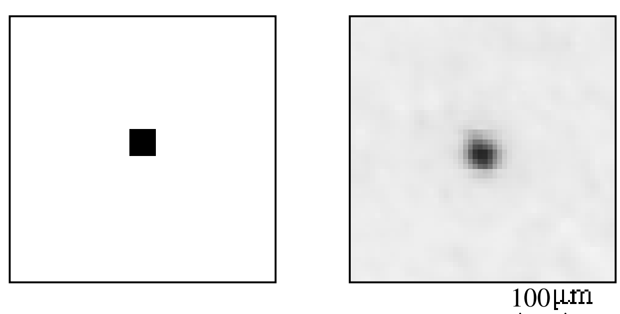

Figure 1(A). B1 (left) and PB1.

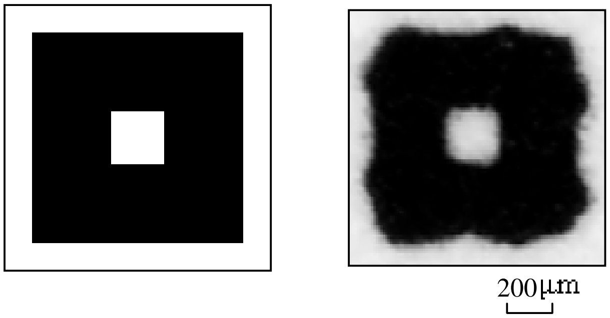

Figure 1(B). W4 (left) and PW4.

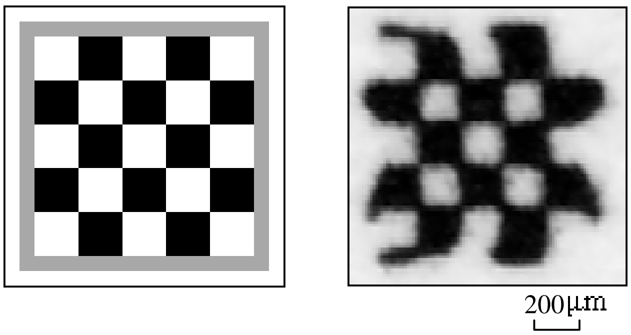

Figure 1(C). C3 (left) and PC3.

Table 1. Description of 12 sample images.

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 cluster of 16x16 dots with a single white dot in the center.
W2	A cluster of 16x16 dots with a cluster of 2x2=4 white dots in the center.
W3	A cluster of 16x16 dots with a cluster of 3x3=9 white dots in the center.
W4	A cluster of 16x16 dots with a cluster of 4x4=16 white dots in the center.
C1	A 16x16 checker pattern in which each square is a single dot.
C2	A 16x16 checker pattern in which each square is a cluster of 2x2=4 dots.
C3	A 15x15 checker pattern in which each square is a cluster of 3x3=9 dots.
C4	A 16x16 checker pattern in which each square is a cluster of 4x4=16 dots.

Results

For each of 12 printed and scanned images we measured three items, one: average of total area of a cluster or clusters, two: standard deviation of the area, three: coefficient of variation of the area. They are shown in Table 2, where 'A' stands for the average area of 100 images, 'S' the standard deviation of 100 areas, and 'C' the coefficient of variation of these areas.

Table 2. (A) the average area of 100 sample images, (S) the standard deviation of the areas, and (C) the coefficient of variation of the areas.

Image	A(µm^2)	S(µm^2)	C
PB1	6200	1202	0.19387
PB2	34350	2613	0.07607
PB3	76810	3768	0.04906
PB4	128890	5289	0.04103
PW1	0	-	-
PW2	11076	2931	0.26463
PW3	42688	4150	0.09722
PW4	89241	5444	0.06100
PC1	1960046	34682	0.01769
PC2	1729275	67170	0.03884
PC3	1208465	58954	0.04878
PC4	1272111	37402	0.02940

Discussion

We can calculate the value of dot gain from the results above as in Table 3.

Table 3. Dot gain of 12 images.

Image	Dot gain (%)	Image	Dot gain (%)	Image	Dot gain (%)
PB1	-13.4	PW1	>300.0	PC1	201.2
PB2	40.7	PW2	193.9	PC2	244.2
PB3	60.6	PW3	135.1	PC3	125.8
PB4	52.5	PW4	110.7	PC4	101.0

Let us show the detailed example in the case of the image PB2. From Table 2, the area of a black cluster in B2, which consis of 2x2 dots, is 34350 µm^2. On the other hand, we can calculate the area of a cluster of 2x2 dots in B2, roughly 85*85*4, and get 28674 µm^2. The difference 34350-28674 is the sum of the dot gains of 4 dots. Considering these 4 dot gains are overlapped each other, we can get the dot gain from this value, which is about 2940 µm^2 or 40 %. A sketch of this cluster is shown in Fig. 2.

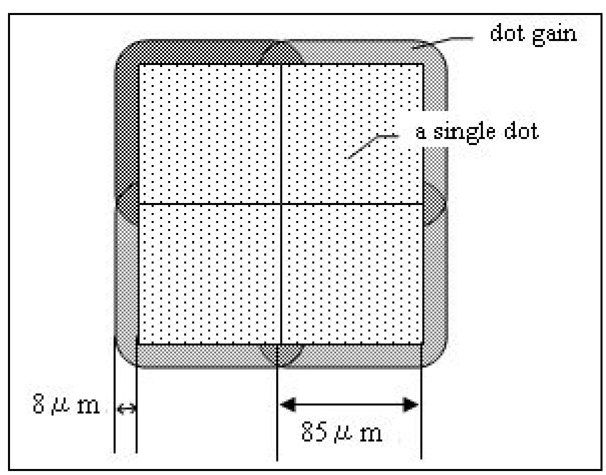

Figure 2. A cluster and dot gain in PB3.

Let us explain more about the dot gain shown in Table 3.

PB1: In this image printed dot size is smaller than that in B1, that means the dot gain is below zero. We think this is because some toner particles disperse or peel off from the paper. We used standad quality paper, so we need to try papers of other quality.

PB2-PB4: By an effect of clustering, each dot has a certain value of gain.

PW1: In this image no white area could be observed, which means a black dot has a gain more than a half of 85 μm, the length of an edge. We can get the dot gain is more than 300 % from this value.

PW2-PW4: Dot gain gets smaller as the cluster size gets larger. In other words, we can say the stability of dot shape increases as the dots gathers in cluster.

Now we discuss the stability of printed images. As shown in the column C of Table 2, the coeffficient of variation of areas tends to decrease as the cluster size increases. This means the stability of the shapes of clusters will increaseand that leads to the increase of stability of the image. We can make use of this trend to control the dot size to be printed.

Conclusion

Shapes and sizes of printed dots were observed from the viewpoint of area. 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 we assume that dot gain decreases as the cluster, black or white, size increases. 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. We should try some other size of clusters and clarify the characteristics of printed clusters such as shape, size, density, dependency on papers, and so on.

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Biography

Kitakubo Shigeru is Assistant Professor of Nippon Institute of Technology. He received his B.S., M.S. 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.