Improvement of the Quality of Digital Printing Using Conditional Halftoning Function

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Abstract

Printed images usually suffer to halftone dot contacts and thus lose their tone details where that contact takes place. Dot contacts should be avoided by means of certain technical approaches as early as image processing stages. This paper begins with the mathematical analysis of the mechanism of dot contact regarding different dot shapes of round, square and diamond. Then experiments were carried out to verify theoretical results derived through outputting single-color chips (20 mm×20 mm) using HP indigo 3550 press with paralyzing its dot gain compensation function. Chips under research were designed with dot area percentages varying from 25% to 80%, and two levels of resolution (600 and 1200 dpi) were used respectively for each dot area percentage. The theoretical analysis showed that dot contacts happened in case of dot area percentage 78.5% for the round dots, 50% for the square dots, 35% (first contact) and 65% (second contact) for the diamond dots, respectively. Jumps in dot density were employed to determine whether the dot contact happened or not. It was observed that halftone dot contacts occurred at the dot area percentage 71% for the round dots, 47% for the square dots, 34% (first contact) and 62% (second contact) for the diamond dots, all lower than their corresponding theoretical values. A conditional halftoning function was designed on the basis of experimental results, which was programmed using the PostScript language. The averaged density difference tested at the 34% of dot area percentage was 0.026, 47% was 0.025, 62% was 0.034 and 71% was 0.041, where the normal halftoning technology was used. In contrast, the averaged density difference was reduced to 0.005 at the 34%, 0.012 at the 47%, 0.016 at the 62% and 0.019 at the 71%, in the case of using conditional halftoning function. These results indicate that the conditional halftoning function is useful for diminishing halftone dot contacts. This study provides a promising halftoning method to improve the quality of digital printing that is subject to the negative effect of halftone dot contacts.

Introduction

Halftone dot contact is a printing phenomenon where individual dots touch when a certain area-coverage value has been reached. This leads to an erratic increase in tone density, also known as tone jump [1]. Tone jump is usually aggravated due to the presence of printing pressure in conventional offset press. In the case of non-impact printing (NIP), the effect of dot contact may be still serious because of the dot gain caused by light entrapment. It worth noting that the effect of dot gain may be mitigated through use of compensation curve at prepress stage, but dot contact can not be avoided with such a technique, for that dot contact is heavily dependent upon dot shape and area percentage value [1,2]. In this paper, we report a conditional halftoning function which intends to diminish dot contact by means of varying dot shapes in light of area percentage values.

Theory and Methods

Theoretical Analysis

Three types of dot structures are commonly used in traditional halftone screens, which are round, square and diamond dots [2]. In theory, dots with different shapes contact at different area percentages, as shown in Fig. 1.

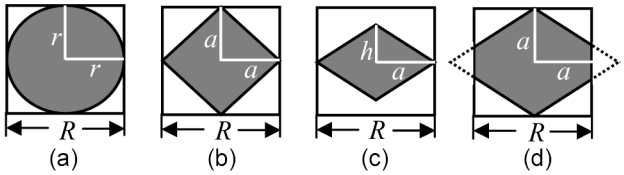

Figure 1. Dot shapes: (a) round; (b) square; (c) and (d) diamond

Assuming that the side of halftone cell equals R, the whole area of halftone cell is R^2. For round dots as illustrated in Fig. 1 (a), the dot area is $\pi r^2=\pi R^2/4$. Therefore, the dot area percentage of round dot that presents dot contact is in theory $\pi R^2/4R^2=0.785$. Following the same calculation approach, dot contact area percentages of the two other dot shapes were obtained, which are 0.5 for square dot, 0.35 (first contact) and 0.65 (second contact) for diamond dot.

Experimental Values of Dot Contact

Single-color chips were designed from 25% to 80% with 1% step of dot area percentage. Chips were printed with HP indigo 3550 using round, square and diamond dots, respectively. The printer was shut up its dot gain compensation function. The substrate used was coating paper of 80 g/m^2. Each dot shape was pulled proof five times using device resolutions 600 dpi and 1200 dpi, respectively. Densities of dot chips were tested and averaged for experimental analysis. The occurrence of dot contact was determined by observing sharp increase in dot density between two adjacent dot area percentages.

Fig. 2 shows averaged values of density difference between two neighboring printed dot patches. It can be seen from Fig. 2 that sharp increases in neighboring density appeared in all the three shapes of dot, implying that dot contact was really happened. For round dot, dot contact happened at the area percentage of 47%; for square dot, dot contact at 71%; for diamond dot, the first dot contact at 34%, and the second dot contact at 62%. Compared with theoretical analysis, experimental values of dot contacts of the

three dot shapes are all lower than their corresponding theoretical values, presumably because there is light entrapment phenomenon.

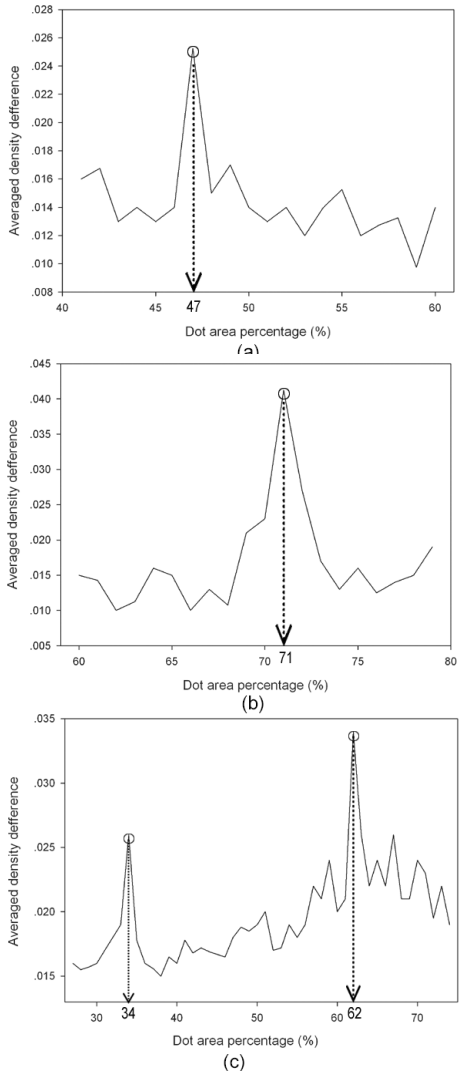

Figure 2. Averaged density differences between two neighboring chips (a) round; (b) square; (c) and (d) diamond

Conditional Halftoning Function

For a halftone cell as illustrated in Fig. 3, a certain number of sub-grids needed to be blacked according to the gray level of digital pixel. Halftoning function is such a tool used to assign which sub-grids to be blacked, in other words the halftoning function determines the shape of halftone dot to be formed. Halftone dots with different shapes require varying mathematical halftone functions. To avoid the occurrences of dot contact, light tone area in an image should adopt round or square dots, medium tone area should use round or diamond dots, dark tone area should employ square and diamond dots, in view of the theoretical and experimental results. In practice, considering the printability of different dot shapes, we designed the conditional halftoning function as the following form:

$$f\begin{cases}1-\left(x^2+y^2\right) & |x|+|y\le 0.7| \quad \text{light area}\\ 1-\left(0.7|x|+|y|\right) & 0.7<|x|+|y|\le 1.25 \quad \text{medium area}\\ \left(|x|-1\right)^2+\left(|y|-1\right)^2-1 & |x|+|y|>1.25 \quad \text{dark area}\end{cases} \tag{1}$$

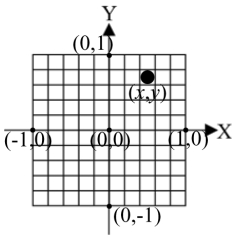

Figure 3. Coordinate graphs of digital halftone cell

The above conditional halftoning function was programmed in the light of the PostScript language, which is:

{abs exch abs 2 copy add .70 le
{dup mul exch dup mul add 1 exch sub
{2 copy add 1.25 le
{0.70 mul add 1 exch sub}
{1 sub dup mul exch 1 sub dup mul add 1 sub}
Ifelse}
Ifelse}bind

The conditional halftoning was implemented through use of the halftoning module in Photoshop 6.0. The working flow is given as in Fig. 4.

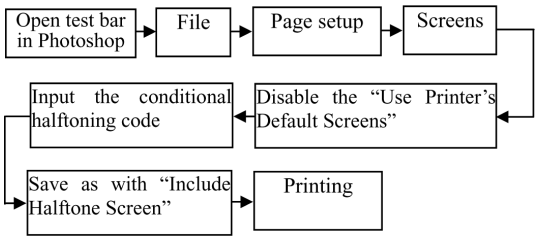

Figure 4. Working flow used for conditional halftoning function

Data acquisition and analysis

Single-color patches were printed using HP indigo 3550. These experimental patches were designed with screen dot area percentages from 25% to 80% with 1% step increased. All patches were designed with identical size of 20mm×20mm, and each area percentage was outputted five times with 600 dpi and 1200 dpi, respectively. Each patch was tested for its dot density, and density values were averaged as the final density value of the patch with one given area percentage. The density difference of patches between two adjacent area percentages was calculated. The density differences calculated from the CHF were compared with those from the NHF at the same area percentage. If the reduction of density difference at the critical area percentage is observed, it can reach the conclusion that the CHF is working.

Table 1 Density differences of printed chips using NHF and CHF

Area percentage	34%	47%	62%	71%	Average
NHF	0.026	0.025	0.034	0.041	0.032
CHF	0.005	0.012	0.016	0.019	0.013

Results and Discussion

Data in Table 1 is the density difference of chips tested at interesting area percentages that were printed using normal halftoning functions (NHF) and conditional halftoning functions (CHF), respectively. It can be seen that density differences of chips were reduced remarkably in the case of CHF in comparison with the NHF. This means that the use of CHF is conducive to moderate the negative effect of dot contact.

Hu [3] discussed that dot contact is resulted mainly from dot expansion, and the dot expansion is typically induced by complex light penetration and the spread and penetration of liquid ink. It is known that the dot contact could be avoided beforehand by means of the use of dot expansion compensation function [3,4]. However, it is quite bored that different printing technologies, including varying printing materials, inks, printing pressure, and printing machines, require different dot expansion compensation functions. This makes it very complicated when using compensation functions of dot expansion. With our method proposed in this article, dot contact, as well as dot expansion, could be depressed to an acceptable level. Moreover, the use of conditional halftoning function is independent of the printing materials, inks, and other printing elements used.

Conclusion

Halftone dot contact is relevant to dot shape and area percentage, which is reflected by dot density jump. This research developed a conditional halftoning function with intent to avoid undesired dot contact. The conditional halftoning function developed was programmed with Postscript language on the basis of theoretical and experimental results. The use of conditional halftoning function was proved to smooth the density difference of printed chips significantly. Therefore, digital printing quality can be improved through use of the conditional halftoning function developed here.

References

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Author Biography

H.-W. Duan received his BS in printing engineering from theXi'an University of Technology (2004) and his PhD in packaging engineering from Jiangnan University (2010). Now he works as a postdoctoral staff in the South China University of Technology. His work has focused on the halftoning technologies and the color science.