The Ink Volume Based Resolution Conversion Method

Hsiao-Yu Han, Meng-Fen Lo, Yao-Wen Huang, Tung-Lin Wu, Chieh-Yi Huang, and Jane Chang, Industrial Technology Research Institute, Hsinchu, Taiwan

Abstract

In this paper, the method for generating print data of any resolutions based on ink volume from the original print data is presented. The print data in the form of halftoned levels are first transferred to the ink image according to the relation between halftone level and drop number obtained by the experiment of ink control. Then, the ink image of original resolution is converted to the ink image of desired resolution by the concept of conservation ink volume per pixel where the amount of ink drops in the unit area stays coherent in the conversion. Finally, each drop number of the converted ink image is transferred to the corresponding halftone level to generate the printing data that can be accepted by the printer. This method can be applied to all the applications related to printing such as printers and multi-function peripherals to save the time and labor in color-related experiments that are the pre-requisite works in developing print modes for different resolutions. The print data of lower resolution can be inputted to the print system to generate higher resolution output. As a result, the memory usage is significantly reduced during the print process. Due to the ink loadings of the image remain identical in the completed resolution conversion process, the goal of maintaining color performance is achieved.

Introduction

With the development of the digital technology, the applications for the digital images are getting broader. Digital images are easy to achieve by digital cameras and scanners. The images are output by an image output equipment such as a digital photo printer in which a memory card slot and a LCD display are included inside. Generally, most kinds of the memory cards shown in the market can be supported so the computer is not the only interface for printing any more. The only thing you need to do to perform print job is plugging the memory card into the slot on the printer and pressing the buttons thereon. The whole procedure becomes much more convenient and faster.

However, digital images usually are composed of trichromatic colors: red (R), green (G), and blue (B) in different proportions. However, a lot of image output devices and displays are not able to produce the enough tints. A digital image must be undergone a color conversion to transfer to a color space for output device before printing. Taking a printer as an example, the color space is formed by cyan (C), magenta (M), and yellow (Y). After that, the image is undergone a down tint process for converting the original multi tints image into a less tints image in order to conform to the characteristics of output devices. This step can be referred to as a halftoning process. The values of the pixels in the halftoning images are responsed to drop numbers of the ink. Finally, a halftoning image is converted and output according to the arrangement of the ink nozzles of the printhead for producing a printed image.

Associated with the advancement of the printing systems and printheads, the resolution for printing has been improved from 300 DPI ten years ago to 4800 DPI presently. Generally, the resolution of a digital image is determined at the time of shooting or scanning. The only thing that can be changed during the printing process is the printing resolution. However, the size of a printout is changed with the variation of printing resolution, which means a higher printing resolution gets a smaller image and vice versa. Thus, an additional process is required for outputting an image with a fixed size when the printing resolution is changed. On the other hand, color-related experiments are needed for a printmode with varied resolutions to obtain the relationship between the halftone levels and drop numbers of the ink, which cost a lot of labor and time, especially for a printmode with a higher resolution.

In order to solve the foregoing problems, in the technique disclosed in Ref. [1], the original 300 DPI printing data are directly repeated in the horizontal direction to make one dot become two dots. To retain the characteristics of original printing data, a correction process will be performed to the doubled printing data. This correction process is a dot removing process, which prevents two adjacent dots from printing at the same time, and forms the virtual 600 DPI printing data. This method can only achieve the 600 DPI printing in the horizontal direction, and the resolution of the data is not a real 600 DPI according to a strict view.

Reference [2] also proposed the method for enhancing the printing resolution in the horizontal direction, where the data are firstly doubled in the horizontal direction to make one dot become two dots. And then, a dot removing process is performed to the edge for the blur effect caused by the doubled printing data. For the regions beside the edges, a checkerboard-like mask is used to reduce the amounts of the printing data, which makes the printing ink as similar as possible before and after the resolution enhancement. This method only improves the resolution in the horizontal direction, and an additional image edge detection process makes this process even more complicated.

In addition, the method provided in Ref. [3] is for improving a printing resolution in the horizontal direction. Instead of directly doubling the printing data, a transition table is utilized to replace a dither table in the halftone process. The same pixel in the original image is continuously compared to the two thresholds in the transition table, twice in horizontal direction. Therefore, two halftone outputs are obtained by the same input pixel. This method is limited by using the dithering method to perform the halftone processing, which achieves halftoning images with poor quality and may even cause ink bleeding and color shift due to the increase of the ink drops per area.

In Ref. [4], duplication or average method is used to increase the dots in the low brightness area, which is less sensitive to human eyes. In the area where the brightness is higher than a threshold value, a table consulting method is used to insert some dots. Firstly, a database including different features of images is produced by experiments where four filter matrixes required by an operation of generating four dots from one dot are represented. In a practical operation, the processing dot is treated as the center of the 9×9 matrix; an eight dimension vector is obtained by subtracting the processing dot from the surrounding eight dots respectively, which is used for searching for one or several sets of filter matrixes in the database by matching operation, which corresponds to the features similar to the processing dot. Finally, the value of the inserting dot is calculated by adding the multiplications of the weighted ratios and the filter matrixes. In this method, the database must be established and stored in the memory when the system is offline. Although a larger database achieves a better image quality, the larger storage size and the longer matching time are needed. On the other hand, different databases are needed for different multiple of resolution conversion, which means a large memory is necessary.

In Ref. [5], the problem caused by doubling the original printing data according to the desirable printing resolution is mentioned, which is that the amount of ink printed on the medium become double such that the color presentation is even worse. Therefore, the mask changed with the printing position is used to remove the redundant printing data to make the amount of ink remain the same with the variation of resolution. Although this method makes the amount of the ink remain the same, the printing data will be changed with the position. In other words, an ink drop originally located in the center will be dispersed to the surrounding location, which makes the printing quality become worse. In this method, color bleeding still happens as two adjacent dots are printing at a high resolution.

According to the description above, when the image is printed at printmodes with different resolutions, the pre-requited experiments for the relations between the halftone levels and drop numbers of ink must be performed. On the other hand, if images stored in a memory card are printed, the size of the printouts will be changed with the printing resolutions. Thus, a new method for converting the printing data and an applied device are necessary to develop to print images at different resolutions and to save the labors and time required in the color-related experiments.

Algorithm

Please refer to Fig. 1, wherein a device for converting printing data is proposed in the paper, comprising: an image input unit, an ink drop corresponding unit for the original resolution, an ink balancing unit and a halftone ink drop processor. The ink balancing unit is established by the conversion table obtained by the principle of the coherent of ink drops per unit area in the original image and the printing image. After an original image of the original resolution is input to an image input unit, the original image will be transferred into an ink image, where the corresponding ink drops per unit area are generated, by the ink drop corresponding unit. The ink balancing unit is then used to convert the ink drops of the ink image to the corresponding positions of the printing image of the printing resolution. Further, a halftone ink drop processor for the printing resolution is used to transfer the ink image into a halftone image for printing.

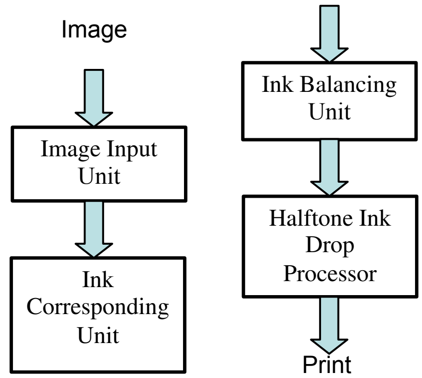

Figure 1. Flow chart for converting the printing data.

Assume the resolution of the original image represented by N bits is $VR_{ori}*HR_{ori}$, in other words, every pixel of the original image has 2^N variations which means that 2^N kinds of halftone levels will be shown in the image. In practical printing, different halftone levels correspond to different amounts of ink drops. Table 1 below shows the relationship between the halftone levels and the numbers of corresponding ink drops for the printing in the original resolution. (For the convenience of discrimination, inks drops corresponding to halftone levels of the original resolution and the printing resolution are called “corresponding ink drops” and “converting ink drops” respectively in this specification. Likewise, the halftone images of the original resolution and the printing resolution are called “halftone image” and “printing halftone image” respectively in this specification.)

Table 1:

Halftone Level	Encoding (N bits)	The number of corresponding ink drops
0	00…0	0
1	00…1	.
.	.	.
.	.	.
2^N-1	11…1	M

Assume the desired resolution for output is $VR_{new}*HR_{new}$, that is, the printing resolution of the original image is converted from the original resolution $VR_{ori}*HR_{ori}$ to the desired resolution $VR_{new}*HR_{new}$. The relationship between the printing halftone levels and the amounts of converting ink drop must be obtained first. In theory, without changing the inks and the used papers, no matter what resolution we choose to print, the amount of ink drop in unit area should stay coherent. According to Eq. (1), the relationship between a pixel of the original image and a pixel of the printing image can be calculated. This relationship is called the Conversion Ratio.

$$CR = \frac{VR_{new} * HR_{new}}{VR_{ori} * HR_{ori}} \quad (1)$$

Table 2:

Original Resolution		Desired Resolution	
Halftone Level	The number of corresponding ink drops per pixel	The number of converting ink drops per unit area	The number of converting ink drops per pixel
0	0	0	0
1	.	.	.
.	.	.	.
.	.	.	.
2^N-1	M	M	M/CR

A pixel of the original image is treated as a unit area, and equals to the CR pixels in the printing image of the desired resolution. According to the concept of equalizing the sum of ink drops within the unit area, the sum of the printing ink drops within the CR pixels in the printing image can be obtained. That is, there are at most 2^N variations of corresponding ink drops within the CR pixels in the printing image. These 2^N variations of corresponding ink drops can be read from Table 1, and the number of the corresponding ink drops is divided by the CR value to obtain the number of converting ink drops. Then the corresponding ink drops shown in the ink image are equally distributed to each pixel inside the CR pixels, such that all possible combinations of the number of the converting ink drops for a pixel can be obtained by statistical method. Table 2 is a conversion table for the halftone levels of the original resolution, and the number of converting ink drops per pixel of the desired resolution.

Table 3:

Halftone Level	Encoding (Q bits)	The number of converting ink drops per pixel
0	00…0	0
1	00…1	.
.	.	.
.	.	.
P-1	11…1	M/CR

In the printing at desired resolution, the number of converting ink drops per pixel is 0 at least and M/CR at most. There are P kinds of numbers of the converting ink drops from 0 to M/CR in numerical order. Thus, Q bits required in encoding the P kinds of number of converting ink drops can be calculated from Eq. (2) where the function MAXINT() means to obtain the maximum integer. In other words, each pixel of the printing halftone image at the desired resolution can be represented by Q bits. Therefore, the relationship between the printing halftone levels and the numbers of the converting ink drops at desired resolution is obtained, as shown in Table 3. This relationship can be provided for encoding the printing halftone image of the desired resolution.

$$Q = MAXINT\,(\sqrt{P}) \quad (2)$$

Experiment Results

The data of the original image of the original resolution 300 × 300 DPI represented by 8 bits is input by the image input unit. In other words, the range of the pixel value is from 0 to 255. The halftone output is encoded by 2 bits: 00, 01, 10 or 11. The relationship between the halftone levels and the number of corresponding ink drops is shown in Table 4, wherein 00 means 0 corresponding ink drop should be localized on the pixel for printing; 01 means 4 corresponding ink drops should be localized on the pixel for printing; 10 means 8 ink drops should be localized on the pixel for printing; and 11 means 12 corresponding ink drops should be localized on the pixel for printing.

Table 4:

Halftone Level	Encoding (2 bits)	The number of corresponding ink drops
0	00	0
1	01	4
2.	10	8
3	11	12

As shown in Fig. 2(a), the size of the original image is 5 × 5 pixels. In the image, the number on the pixel means the halftone level after encoded. After the halftone image shown in Fig. 2(a) is transferred to the corresponding ink drops by Table 4 of the ink drop corresponding unit, an ink image is obtained as shown in Fig. 2(b).

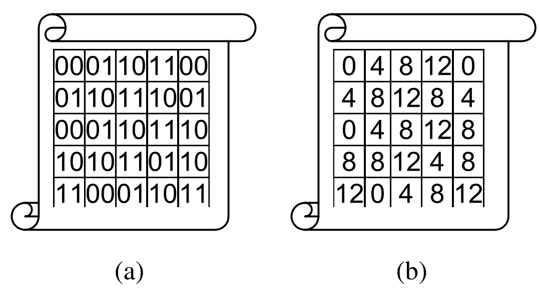

Figure 2. Test image of original resolution 300 × 300 DPI, (a) Original Image; (b) Ink image

If the original image is printed by 600 × 600 DPI, the first thing is to obtain the table about the relationship of the halftone levels and the number of converting ink drops for the 600 × 600 DPI. The CR value is 4 which is calculated from the Eq. (1). It means that one pixel at 300 × 300 DPI equals to four pixels at 600 × 600 DPI. One pixel at 300 × 300 DPI is considered as a unit area. Due to the amount of ink drops in a unit area never changes, the number of ink drops in the CR pixels at 600 × 600 DPI is the same as the number of ink drops in the unit area at 300 × 300 DPI. The number of converting ink drops is obtained by dividing the number of corresponding ink drops by the CR value. Thus, the relation between the number of the converting ink drops per pixel and the number of corresponding ink drops per pixel is built in Table 5.

Table 5:

Resolution: 300 × 300 DPI		Resolution: 600 × 600 DPI	
Halftone Level	The number of corresponding ink drops per pixel	The number of converting ink drops per unit area	The number of converting ink drops per pixel
0	0	0	0
1	4	4	1
2	8	8	2
3	12	12	3

Next, according to the ink drop conversion table (Table 5), each pixel in the ink drop image at 300 × 300 DPI is converted to four pixels at 600 × 600 DPI by the ink balancing unit 30. The number of the converting ink drops within the four pixels is the same as the number of corresponding ink drops of one pixel at the original 300 × 300 DPI. In other words, ink drops per pixel at 300 × 300 DPI are distributed to four pixels at 600 × 600 DPI averagely. After all conversions of the pixels in the original image are completed, a printing ink image of 600 × 600 DPI can be obtained, as shown in Fig. 3.

0	0	1	1	2	2	3	3	0	0
0	0	1	1	2	2	3	3	0	0
1	1	2	2	3	3	2	2	1	1
1	1	2	2	3	3	2	2	1	1
0	0	1	1	2	2	3	3	2	2
0	0	1	1	2	2	3	3	2	2
2	2	2	2	3	3	1	1	2	2
2	2	2	2	3	3	1	1	2	2
3	3	0	0	1	1	2	2	3	3
3	3	0	0	1	1	2	2	3	3

Figure 3. Ink image for printing in resolution 600 × 600 DPI.

With the desired resolution 600 × 600 DPI, the number of ink drops printing on one pixel is 0 at least and 3 at most. There are four different numbers of ink drops so the number of bits required for these four different numbers of ink drops is 2, which is obtained from Eq. (2). Therefore, each pixel of the printing halftone image for 600 × 600 DPI can be represented by 2 bits, such that a corresponding table about the relation between the halftone level and the number of converting ink drops can be obtained for 600 × 600 DPI, as shown in Table 6. This corresponding table is provided for encoding the printing halftone image for 600 × 600 DPI.

Table 6:

Halftone Level	Encoding (2 bits)	The number of converting ink drops per pixel
0	00	0
1	01	1
2	10	2
3	11	3

Finally, the printing ink image is processed by Table 6 of the halftone ink drop processor to output a corresponding halftone image for the printing device as shown in Fig. 4. This printing halftone image is provided for printing in 600 × 600 DPI.

00	00	01	01	10	10	11	11	00	00
00	00	01	01	10	10	11	11	00	00
01	01	10	10	11	11	10	10	01	01
01	01	10	10	11	11	10	10	01	01
00	00	01	01	10	10	11	11	10	10
00	00	01	01	10	10	11	11	10	10
10	10	10	10	11	11	01	01	10	10
10	10	10	10	11	11	01	01	10	10
11	11	00	00	01	01	10	10	11	11
11	11	00	00	01	01	10	10	11	11

Figure 4. The printing halftone image for printing in resolution 600 × 600 DPI.

In addition, although the converting number of ink drops calculated from the corresponding ink drops in the ink balancing unit 30 is not an integer, the equalization principle also must be conformed, which means that the number of ink drops per CR pixels at the desired resolution must be the same as the number of ink drops per pixel at the original resolution. Under this situation, the numbers of ink drops in the CR pixels are not equal to each other, therefore part of the CR pixels are set to the value larger than the number of converting ink drops, and part of the CR pixels are set to the value smaller than the number of converting ink drops. For example, if a corresponding number of ink drops deposited on one pixel of the original resolution 300 × 300 DPI is 1, the CR will be 4 for printing in the desired resolution 600 × 600 DPI. At this time, it is not possible to distribute one ink drop to 4 pixels; however, the equalization principle also must be conformed. Thus one possible distribution of the number of the converting ink drops for these four pixels at 600 × 600 DPI can be 1, 0, 0, and 0.

Conclusion

The method proposed in the paper is provided for converting the printing data, comprising the following steps: firstly, inputting an original image with the original resolution; transferring the original image in the form of halftone levels into an ink image, where the values are corresponding to the numbers of ink drops per unit area; equally distributing the ink drops of the image to the corresponding positions of the image with the printing resolution to produce an ink image of the printing resolution; converting the printing ink image into a printing halftone image; outputting the printing halftone image.

Compared to the previous methods, in most of their methods, the printing resolution only can be changed in the horizontal direction, and only conversion from the low resolution to the high resolution are performed. In addition, most of the conversion ratio in their method is 2. However, in the proposed method, the conversion ratio is not limited, and no matter the conversion is from high resolution to low resolution or vice versa, the conversion can be performed. Therefore, an image can be printed in an arbitrary resolution.

Further, during the process, the halftone image can be obtained by the conversion without any color-related experiments. Through the experiments, compared to the original image, the image converted the resolution of printing data by this method maintains the same printing quality and the same color as the original one.

References

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Author Biography

Hsiao-Yu Han received the B.S. degree in electrical engineering from National Taiwan University of Science and Technology, Taipei, Taiwan, R.O.C., in 1999, and the M.S. degree in electrical and control engineering from National Chiao-Tung University, Hsinchu, Taiwan, R.O.C., in 2001. Since 2001, he has been an engineer at Opto-Electronics & Systems Laboratories in Industrial Technology Research Institute, Taiwan. His current researches are in the areas of image processing, printing system, and machine vision.