A Method of Resolution Enhancement Technique Using a Weighted Value According to Locations of Reference Pixels

Ho-Keun Lee, Sang-Youn Shin, Sang-Ho Kim, and Don-Chul Choi, Samsung Electronics Co. Ltd., Suwon, Gyeonggi-Do, Korea*
**Korea Aerospace Research institute, Daejeon, Korea*

Abstract

Many resolution enhancement techniques have been developed and used to convert a low resolution image into a higher resolution image in a printing system. Generally, the print-out of the high resolution images has more density levels than that of the low resolution images. It means that the high resolution image has more bits for each pixel than the low resolution image. In this paper, we propose a resolution enhancement method which can make a multi-bit image from a 1bit image. The present method generates a multi-bit image by improving the uniformity in each halftone pattern for each super-cell. Based on the edge map generated by a window having a size of n×n pixels and a LPI (lines per inch) value and an angle of the screen mask, the 1bit image is converted to a multi-bit image adaptively. Experimental results show 1bit image has multi level density variously according to its edge map.

Introduction

There is a printing system such as a laser printer that has a 1-bit page memory buffer providing a cost-effective system. As the power of a personal computer is strong, manufacturer doesn't have to give more power to the printing system. All image processing including color conversion, halftoning, compression, and etc. has done in the computer side. In such a system, transferring data size is important to speed up and normally halftoned image data are transferred to the printing system. Then, in the system, the halftoned binary image is converted into the multi-valued image. It permits to have a high image quality without increasing the image data size. Therefore, this system can save not only the data-storage capacity but also data-retrieving time and improve the quality of the printed image. In order to achieve such a result, many researchers introduced filtering or smoothing methods as inverse halftoning. The inverse halftoning, also referred to as descreening or unscreening, is a process that reconstructs a multilevel image from a binary halftone version of the original [1]. When we use the inverse halftoning for enhancing printing resolution, a problem is that the quality of a text area is very poor since smoothing methods degrade the sharp edges of a halftoned binary image and cannot keep the structure of original halftone patterns [2].

Bit image Resolution Enhancement

The proposed paper uses a smoothing method which requires the LPI and the angle of screens used in halftoning process. The halftoned image is grouped into two areas such as a non-edge area and an edge area depending on their characteristics. Each area is corrected by replacing the original 1bit value with the multi-level value. The multi-level value is achieved to increase the uniformity in the halftoned image. In order to generate the multi-level value, we need to receive the screen information, for example, a screen angle, a LPI and positions of dot-centers. When the distribution of dot centers is not uninformative in an N×N window, it can be improved by generating the multi-level value.

Image separation

The first step of 1bit-image resolution enhancement is to separate an input binary image to two areas as non-edge areas and edge areas pixel by pixel. The input binary data is stored in a memory and an N×N window image is sampled from the memory. In the N×N window image, several sub-windows are generated and the variation between each sub-window is evaluated to separate the input image. For each separated area, the dot-center variation is improved by reducing the irregular halftone pattern.

The binary N×N image window sampled from the line buffer and sub-windows are organized in the N×N image window by using the screen information. Each sub-window center coordinate is informed of the screen information.

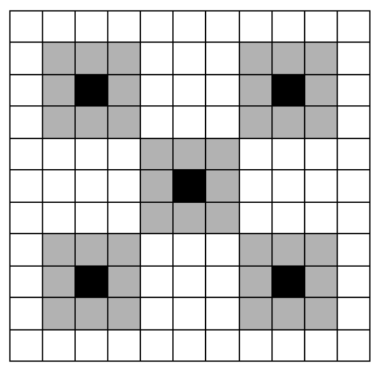


***Figure 1**. 11x11 window sample*

Fig. 1 shows the 11×11 window and the sub-windows. Grey areas represent the sub-windows and dark pixels are their centers. Their structure is based on an example for 141LPI, 45degree screen. Each pixel in the 11×11 window has a '1' or '0' value. In the color printing system, each color channel has its own screen information, therefore, the 11×11 window organization for each color is different. In case of Fig.1, the window for 141LPI, 45degree screen has 5 dot centers. The sub-window has a 3×3 window size.

Now, the input 1bit data pattern in each sub-window is analyzed to decide whether the current 11×11 window is in the edge area or non-edge area. In order to do that, the coincidence for each sub-window pattern is evaluated. For each pixel at the same coordinate of each sub-window, the edge area is easily detected by counting the number of the pixels that has the same value for all sub-windows at the same position for each sub-window. For example, in Fig. 2, each sub-window has 9 pixels. For the 6 dark grey colored pixels, all sub-windows have same values at the same position for all sub-windows. But for the light grey 3 pixels, all sub-windows don't have same values. Only 3 sub-windows have same pattern. Overall, 6 pixels for each sub-windows have same value and that pixel number is compared with the threshold to decide whether this window is in the edge area or non-edge area. Before performing the smoothing process, it is determined whether the window region is an edge region or not. This is because a boundary of the edge area becomes scattered when the edge is enhanced, and accordingly, the edge should not be enhanced.

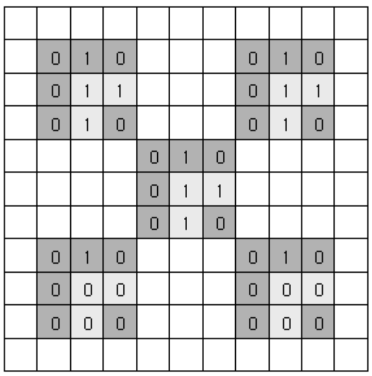


***Figure 2**. The input pattern for finding edge area*

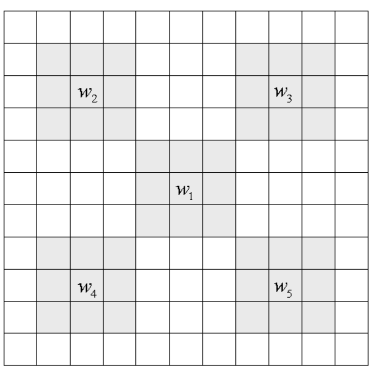
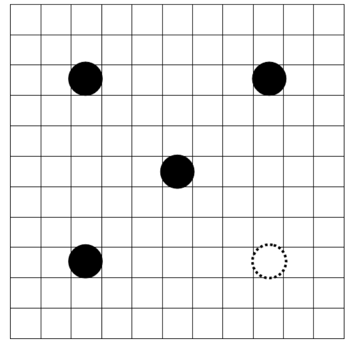


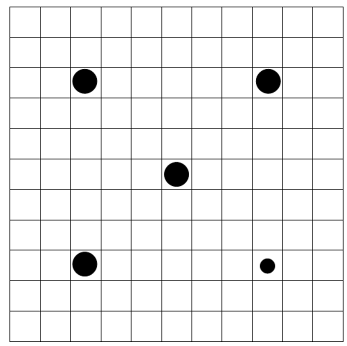
***Figure 3**. The weight parameters on screen dot centers*

Non-Edge Enhancement

In the non-edge area, the variation for referred dot centers is analyzed and compensated. The 1bit halftone pattern is easily recognized if each dot center value is not equal. If a current pixel value is darker than surrounding dot centers, it becomes lighter and surrounding dot centers become darker. On the contrary, a current pixel value is lighter than surrounding dot centers, it becomes darker and surrounding dot centers become lighter. Each dot center has its own weight value as in Fig. 3. For example, the referred dot centers are not equivalent in Fig. 4(a).



(a)



(b)

***Figure 4**. The center pixel distribution for a dark pixel: (a) the input image and (b) the processed result*

The current (center) dot is corrected by decreasing the original density. If this procedure is processed consecutively for all pixels, every dot center in the 11×11 window changes to Fig. 4(b). Also, the weight function can be applied to the window. Each dot center has their weight factor. The corrected dot value is defined as follows:

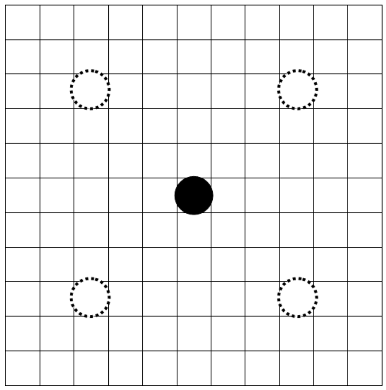
Corrected_dot_value=

$$(W_1 \times \mathrm{dot}_1 + W_2 \times \mathrm{dot}_2 + \cdots\cdots + W_n \times \mathrm{dot}_n)/(W_1 + \cdots\cdots W_n). \quad (1)$$

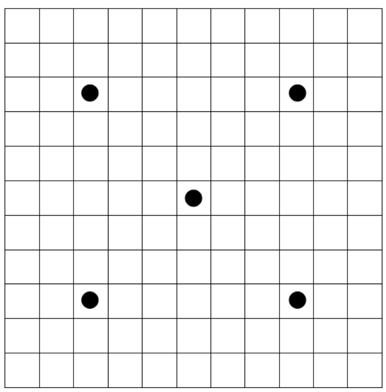
If a current pixel value is the only dark pixel among surrounding dot centers, it becomes lighter and surrounding dot centers has some values in Fig. 5(a) and (b).

Edge Enhancement

If only non-edge area is converted into multi-valued area, the artifact happens between multi-valued area and 1bit halftoned area. The halftone pattern in the edge area is more outstanding when only the non-edge area is enhanced.

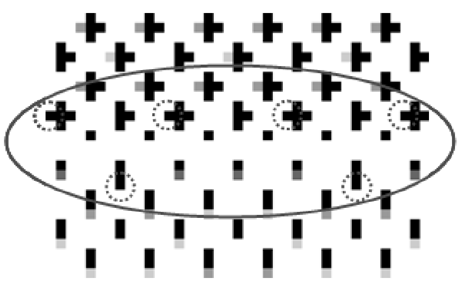


(a)

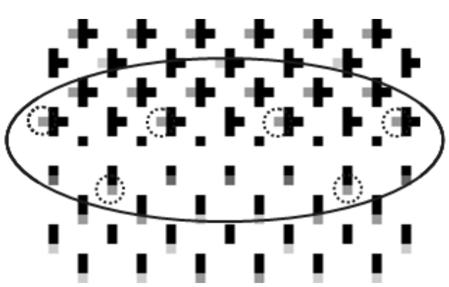


(b)

Figure 5*. The center pixel distribution for a single dark pixel: (a) the input image and (b) the processed result*



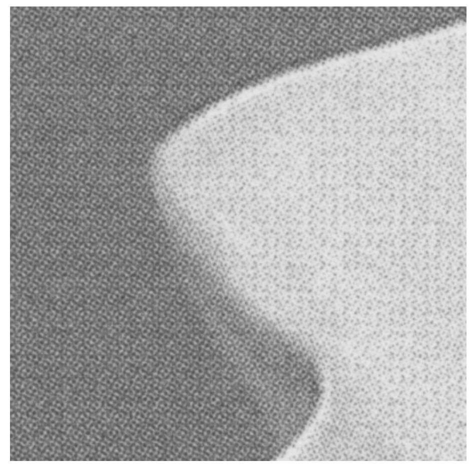
(a)



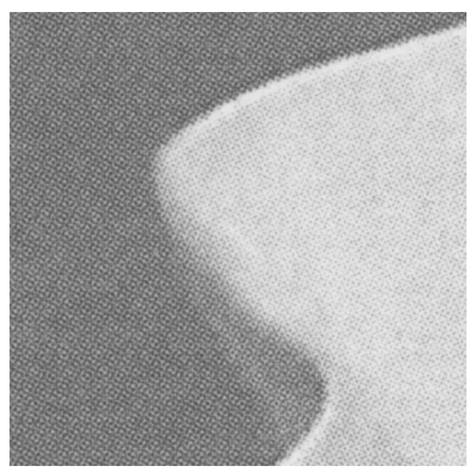
(b)

Figure 6*. (a) Edge area before enhancement (b) edge area after enhancement*

In Fig. 6(a), the elliptical area is the edge area. The dotted circular dots are easily detected by users because they have a different dot density with a enhanced dot density in the neighbor. In Fig. 6(b), the dotted circular dots have the corrected dot density. The original dot density of the circular dot in Fig. 6(a) is darker than the surrounding dot density. Therefore, it should be lighter than the original density to make the total area density equivalent both non-edge area and edge area. But if the dot density in the edge area is changed in the same way that the non-edge area is enhanced, the edge area gets blurred. Because the white dots near the edge area can gain the dot density in the non-edge area. Therefore, when the edge area is enhanced, additional conditions are needed to check whether the current edge sharpness is affected by enhancement or not. In order to do that, the weighting values are adjusted by the condition of edge areas.



(a)

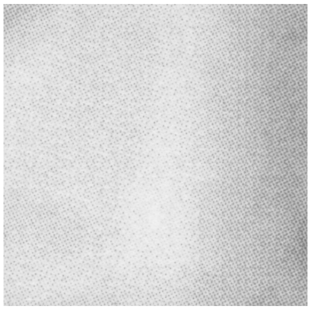


(b)

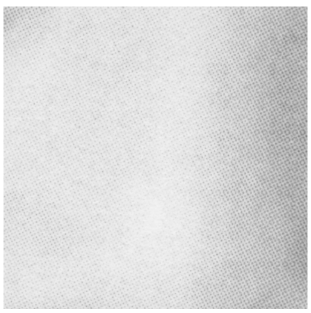
Figure 7*. (a) The original image and (b) the processed image*

Experiments and results

The result images are presented in Figs. 7 and 8. Fig. 7(a) and Fig. 8(a) are the 1bit input images. Every dot has only 2 states "on/off." Therefore the image surface is rough and the halftone pattern is easily detected. Figs. 7(b) and 8(b) are the multi-leveled image. In Figs. 7(b) and 8(b), the repetitive pattern caused by the screen table characteristic is quite reduced and the image tone changes softly in the gradient image area. So, this algorithm is more useful to print a photo image such as a face.



(a)



(b)

***Figure 8**. (a) The original image and (b) the processed image*

Also it is effective to save hardware resources because it provides the high quality multi-leveled image with a 1bit binary data.

Conclusion

We proposed the method to convert a 1bit binary image into muti-leveled image that has a variety of dot levels. The smoothed printed image is achieved. In order to keep the edge sharpness, the input image is separated into the edge and the non-edge area and each area is corrected depending on their characteristics. Each pixel has more various dot density levels than the 1bit input image. Therefore we can get rid of the repetitive pattern that is not uniformative generated by the screen table. We can implement the high speed and high quality printer by generating the multi-leveled image and saving the hardware resources.

References

[1] Henry R. Kang, Digital Color Halftoning(SPIE & IEEE press, Bellingham, WA, 1999), pg. 471.

[2] S. Forchhammer and K. S. Jensen, "Data compression of scanned halftone images," IEEE Trans. Commun., Vol. 42, pp. 1881-1893(1999)

Author Biography

Ho-Keun Lee received the MS and PhD degrees in electronics from Kyungpook National University, Daegu, Korea, in 2000 and 2004, respectively. Since then he joined the digital printing division of the Samsung Electronics Co., Korea. His research interests include color-based object recognition, and color image processing for printing.