Image Processing System for Image Enhancement and Halftone Processing

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Abstract

In this paper, an image processing system we proposed combines the halftone method and image enhancement technique for processing halftone and improving image performance in one pass of the data. The system includes an image input module, an image enhancement module and a halftone module. The image input module sends the original image data to the image enhancement module to enhance the image by filtering. Without storing the result to memory, the halftone module immediately processes the enhanced image data by the algorithm of error diffusion. In our system, the halftone image will be obtained and get improved at the same pass of the data. The system combines two different processes into one step to simplify the hardware architecture and to decrease the access of memory.

Introduction

Generally speaking, the digital images displayed on computers are composed of the red (R), green (G), and blue (B) colors in different proportions. Taking a 24-bit image as an example, the R, G, and B colors are represented in 8 bits respectively. In other words, the color level in each color ranges from 0 to 255. For example, if the levels of R, G and B are all zero, the color is black. If the levels of R, G and B equal to one, the color is white. However, problems occur when the digital image is to be output from the computer. The problems due to that many printing and display devices can only produce binary images. Therefore, in order to conform to the characteristics of output devices, images with many color levels have to be converted into binary images. This conversion method is called halftone.

The halftone method utilizes the illusion of human eyes toward shades to produce the feeling of multiple color levels. Take a printer as an example and suppose a small square on paper is a unit area. Different filling levels inside the unit correspond to different color levels. If an observer looks at this square from a distance, he or she will not notice the variation of the brightness inside the square but treat the square as a whole. What the observer sees is the average brightness of the square.

According to the number of points of the original image needed for one pixel of halftone processing, the halftone processing is generally distinguished into two methods: the single-point processing and neighboring-point processing. For the single-point processing method, the halftone output is usually obtained by sending each pixel of the original image through a predetermined mask. A representative example is the dither method. For the neighboring-point method, the halftone output cannot be obtained from a single pixel comparison but by filtering. A representative is the algorithm of error diffusion. Since the error diffusion method renders better results such as fewer artifacts, this method is often used to obtain high-quality halftone image output. Nonetheless, a drawback of this method is that it involves complicated computation. For a single pixel of halftone image, several multiplications and additions involving its neighboring points are needed.

The purpose of halftone processing for a color image is to comply with the characteristics of an output device. As the halftone processed image is reduced in its color levels, the output quality is often not as good as the original one. If the image quality of the original one is very poor, e.g. image with noises or blurred image, the output halftone image will be even worse. To solve this problem, one usually performs image enhancement to the original image before halftone processing. In this case, the algorithmic structure and computational complexity are increased, and the memory requirement is more.

On the other hand, both multi-function peripherals (MFP) and photo printers make use of the halftone technique. In the copy procedure of the MFP, a color document can be directly scanned and printed. This process is completely independent, without being processed by the computer. If there does not exist any mechanisms to enhance the image in MFP, the output quality will be solely determined by the original document. Once the original document has some defects, the printing output will also have defects. Similar situations also happen to the photo printer. General photo printers have devices for plugging in a memory card. There are many image files that maybe saved or shot by users in the memory card. The user selects an image from memory card to print. Since this procedure does not involve with computer processing either, the output quality will be determined by the original image. In these cases, the output quality improvement has to be done at the input end. As a result, many different techniques can be applied to improve the quality.

A solution is provided by Seiichiro Morikawa and others.[1] where a smoothing circuit is used to select an appropriate filter from a filter storage unit. Corresponding values in a color conversion table are then used for the filter to smooth the image. However, this method directly changes the color of the image, and this may affect the overall image quality. In Ref. [2], halftone processed images are passed through a low-pass filter to achieve the smooth effect. Since this method smoothes the images that have been halftone processed, its effects are thus very limited. Pattern recognition is used for the smoothing task on halftone processed images.[3] First, the sharp patterns in a halftone image that are predefined by the system are detected. Then, these sharp patterns are replaced by predetermined smooth patterns. At least two steps are required in this method: detection and replacement. In detection part, since the whole image has to be scanned pixel by pixel, a lot of time is wasted. In other aspect, the more sharp patterns are predefined, the longer it takes to detect them. Therefore, this kind of methods is very impractical. In Ref. [4], the halftone is performed by error diffusion. In this method, a filter control circuit is used to select the error diffusion filter according to the gray values in pre-segmented region of the image. However, the change of values in the error filters only affects the noises and repeated patterns generated by the halftone process. The quality of the original image almost is not improved.

An image processing system is proposed in this paper. In the system, halftone method and image enhancement technique are combined to obtain the halftone image and improve its quality in the mean time.

Algorithm

The image processing system that combines the image enhancement and halftone techniques is mainly applied to image output devices, such as printers and multi-function peripherals (MFP). As shown in Fig. 1, the data processing systems of the printer or MFP include a color conversion module, a halftone processing module, a data formatter, and a print control module. The image to be printed exists in the data of three primitive colors: red, green and blue (RGB). First, an image is sent to the color conversion module and gets converted into color coordinates, from the three primitive colors to printing colors. The halftone module transfers a multi-bit image into at least one-bit image color by color. The halftone image is arranged by the data formatter into the format required for printing. Taking an inkjet printer as an example, the halftone output image is arranged in the format of inkjet nozzles at this step. Finally, the print control module receives printing data and generates dots to perform the image on a medium.

In the proposed image processing system, the original halftone processing module is replaced with the system shown in Fig. 2 that an image input module, an image enhancement module, and a halftone module are contained in. The original image data I[m,n] which are directly sent to the image enhancement module is obtained through image input module.

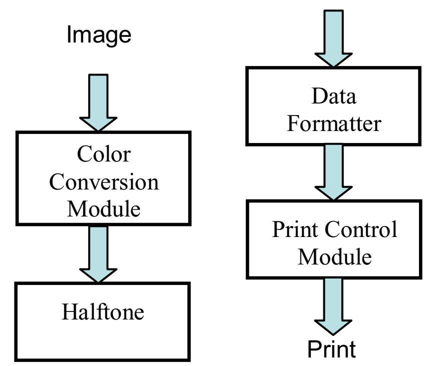


Figure 1. Flow chart for printing system.

The image enhancement module is mainly in the form of a filter. Its algorithm roughly can be written as:

$$O[m,n] = \sum_{k,r} I[m-k,n-r] \times a[k,r] \tag{1}$$

where I[m,n] are the original image data, O[m,n] are the image enhanced data, and a[k,r] are the filters. It can be implemented by smoothing as in table 1 or by sharpening as in table 2.

Table 1. Smoothing Table

1/9	1/9	1/9
1/9	*1/9*	1/9
1/9	1/9	1/9

Table 2. Sharpening Table

0	1	0
1	*1*	-1
0	-1	0

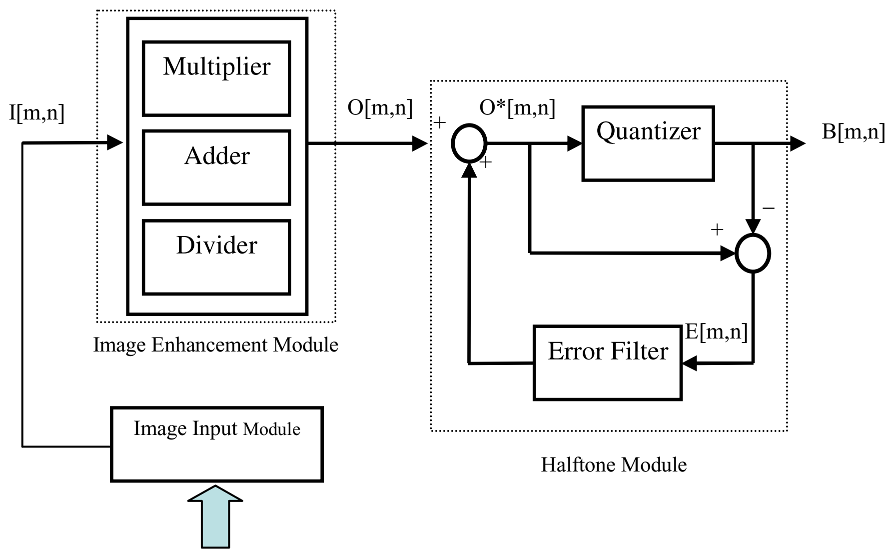


Figure 2. Block diagram of the image processing system.

No matter which type of filter is used, the letter in the italic font of the filter corresponds to the processed pixel of the original image data. A multiplier multiplies the pixels and its neighboring pixels by predetermined weights (numbers in the tables) to obtain a set of weighted values. An adder accumulates the weighted values of the processed pixel to obtain a sum. Finally, a divider is used to divide the sum by the sum of the predetermined weights, and the image enhanced datum for the pixel being processed is obtained.

Then, the enhanced data O[m,n] are sent to the halftone module. The algorithm is shown as equation (2)~(4).

$$O^*[m,n] = O[m,n] + \sum_{k,r} E[m-k, n-r] \times a[k,r] \tag{2}$$

$$E[m,n] = O^*[m,n] - B[m,n] \tag{3}$$

$$B[m,n] = \begin{cases} 1, & O^*[m,n] \geq \frac{2(D-1)-1}{2(D-1)} \\ \frac{D-2}{D-1}, & \frac{2(D-1)-3}{2(D-1)} \leq O^*[m,n] < \frac{2(D-1)-1}{2(D-1)} \\ \vdots & \\ \frac{2}{D-1}, & \frac{3}{2(D-1)} \leq O^*[m,n] < \frac{5}{2(D-1)} \\ \frac{1}{D-1}, & \frac{1}{2(D-1)} \leq O^*[m,n] < \frac{3}{2(D-1)} \\ 0, & O^*[m,n] < \frac{1}{2(D-1)} \end{cases} \tag{4}$$

where the image enhanced data O[m,n] usually ranges between 0 (White) to 1 (Black). B[m,n] are the output from a quantizer and is one of the D values as follows:

$$0, \frac{1}{D-1}, \frac{2}{D-1}, \ldots, 1.$$

The thresholds in the quantizer are fixed at specific values. If the threshold values are equally divided, they are

$$\frac{1}{2(D-1)}, \frac{3}{2(D-1)}, \ldots, \frac{2(D-1)-1}{2(D-1)}.$$

E[m,n] is error signal after quantization and is obtained by taking the difference between the signal before and after quantization. After E[m,n] passes through the error filters, correction signals is produced to correct future inputs. O*[m,n] is the corrected signal. a[k,r] are the error filters (the values in the filters are weights of the error signals, and [k,r] refer to the propagations of the error signals).

Combining the above-mentioned algorithms, one obtains:

$$E[m,n] = O[m,n] - B[m,n] + \sum_{k,r} E[m-k, n-r] \times a[k,r] \tag{5}$$

Common error filters are shown in Table 3 where * refers to the pixel to be diffused.

Table 3. Error Filter, (a) Floyd and Steinberg; (b) Jarvis, Judice and Ninke.

	*	7/16
3/16	5/16	1/16

(a)

		*	7/48	5/48
3/48	5/48	7/48	5/48	3/48
1/48	3/48	5/48	3/48	1/48

(b)

Combine the algorithms of the image enhancement module and the halftone module, we obtain

$$O*[m,n] = \sum_{p,q} O[m-p,n-q]\times a[p,q] + \sum_{k,r} E[m-k,n-r]\times c[k,r] \quad (6)$$

$$E[m,n] = O*[m,n] - B[m,n] \quad (7)$$

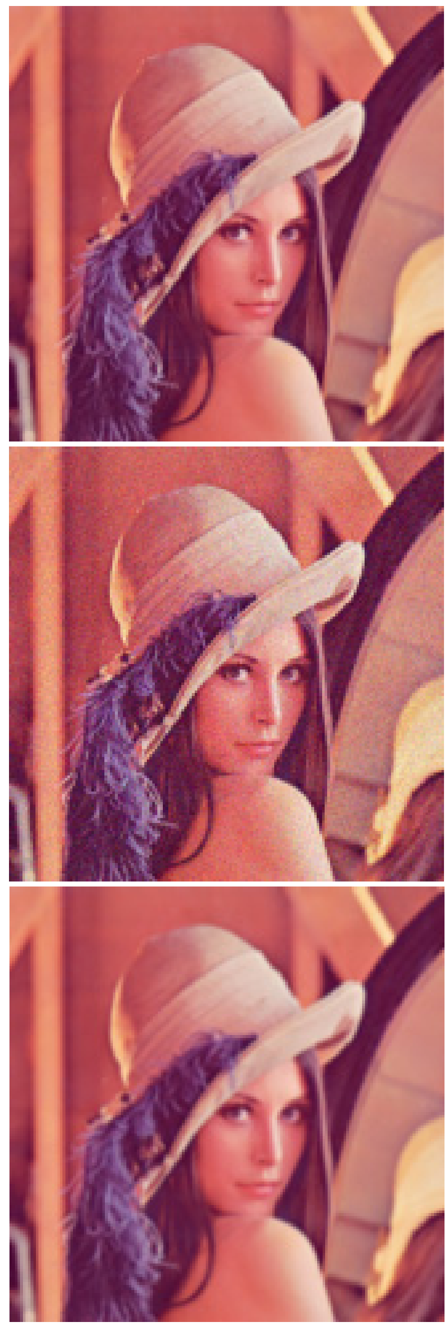
$$B[m,n] = \begin{cases} 1, & O*[m,n] \geq \frac{2(D-1)-1}{2(D-1)} \\ \frac{D-2}{D-1}, & \frac{2(D-1)-3}{2(D-1)} \leq O*[m,n] < \frac{2(D-1)-1}{2(D-1)} \\ \vdots & \\ \frac{2}{D-1}, & \frac{3}{2(D-1)} \leq O*[m,n] < \frac{5}{2(D-1)} \\ \frac{1}{D-1}, & \frac{1}{2(D-1)} \leq O*[m,n] < \frac{3}{2(D-1)} \\ 0, & O*[m,n] < \frac{1}{2(D-1)} \end{cases} \quad (8)$$

Experiment Results

The proposed algorithm for image processing is implemented on a Pentium III 1GHz PC with 512MB RAM and programmed on Borland C++ Builder 5.0. The experiments are mainly partitioned into two parts: smoothing and sharpening. The 24-bit test images of size 512 × 512 are shown in figure 3 where (a) is the original image of Lena, (b) is (a) with noises, and (c) is (a) after blurred effect. In the smoothing experiment, the smoothing filter as shown in table 1 is used in the image enhancement module. After figure 3(a) is processed by general halftone module, figure 4 is obtained. Figure 5(a) is the output from the system we proposed corresponding to the input, figure 3(a). Compare figure 4 with figure 5(a), obviously, figure 5(a) is smoother, especially at the complicated parts or edges in the original image such as the decoration of the hat and hair.

In figure 4(b), the image is obtained from general 2-step method. It means that the image in figure 3(a) is first passed through a smoothing filter to get a smooth Lena which is then stored to the memory. At the second step, the stored Lena read from memory is processed by the halftone module to obtain the halftone image. Although the smooth effects are both shown in figure 4(b) and 5(a), the storage size and processing speed are so different. In the Lena case, the storage size is reduced about 768 Kbytes in our system. Correspondingly, without storing the smooth image to memory, the access time to memory is much less; hence the processing speed is higher.

After figure 3(b) generated by adding Gaussian noises is sent to the system, a halftone image as illustrated in figure 5(b) is achieved. It is clear that the noises originally existed in figure 3(b) are not apparent to see in the corresponding locations in figure 5(b). That's due to that the noises are distributed to the neighbors in our method.



(a) (b) (c)

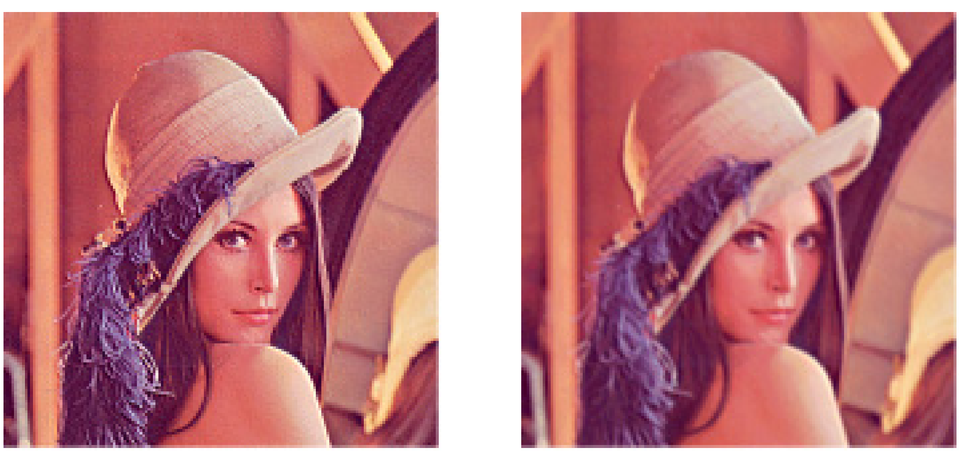
Figure 3. Test images, (a) Lena; (b) Lena with noises; (c) blurred Lena.

(a) *(b)* *(c)*

Figure 4. General system, (a) Figure 3(a) after halftone processing; (b) two-step process for smoothing and halftone; (c) two-step process for sharpening and halftone.

(a) *(b)*

Figure 5. Smoothing experiments, (a) input: Lena; (b) input: Lena with noises.



(a) *(b)*

Figure 6. Sharpening experiments, (a) input: Lena; (b) input: blurred Lena.

In the second experiment, sharpening experiment, the smoothing filter is replaced with sharpening filter shown in table 2 in the image enhancement module. The result of inputting the image shown in figure 3(a) to the system is in figure 6(a). Compare figure 4 with figure 6(a), the details of the original image, figure 3(a), are more apparent to see in figure 6(a).

In figure 4(c), the image is obtained from general 2-step method. Make a comparison to figure 4(c) and 6(a), the sharpen effects are apparently in both images. As discussed in smoothing experiment, the storage size is smaller and the processing rate is higher in our system.

Then, a blurred image shown in figure 3(c) is acquired to the system, therefore, a halftone image, figure 6(b), is achieved. Observe the images, we find that the halftone image looks sharper than the original blurred image, particularly at the hair of Lena and decoration of her hat.

Conclusion

In this paper, the system we proposed is for halftone processing and image enhancement with one pass of the data. There are three modules in the proposed image processing system: an image input module, an image enhancement module, and a halftone module. The image input module obtains the original image. The image enhancement module directly enhances the original image data and sends it to the halftone module. Since the original image data are directly enhanced before halftone processing, the image quality is greatly enhanced without affecting the original contents. The system simultaneously completes the image enhancement and halftone processing.

Through the experiments, the system we develop is able to obtain enhanced halftone images. Our system features the followings:

1. With combined architecture, the hardware of the system is simple to implement.
2. Since halftone processing and image enhancement are executed at the same pass of the data, the result of image enhancement doesn't need to be stored. Therefore, the usage of memory is reduced and correspondingly, the access of memory is less.
3. The structure of the system is flexible so that the enhancement module can be changed to any kinds of filter.

Our system can be used in any applications where the halftone processing is needed such as MFP and photo printers in which the processing must be performed at local device, and independent with computers. By applying the developed system, the quality of the output can be improved according to the enhancement module corresponding to the image content. For example, if the original image is full of noises, the smoothing filter should be use to make the halftone image look smoother.

References

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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.

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