Pseudo-Random Dot Pattern Method in Digital Halftoning

Chaiyapoj Netsiri, Norimichi Tsumura, Hideaki Haneishi and Yoichi Miyake
Faculty of Engineering, Chiba University, Japan
Michael A. Kriss
University of Rochester, New York

Abstract

Strong moiré patterns sometimes appear in the reconstruction of optically scanned halftone images. Various dither methods such as an error diffusion and a blue noise mask have been proposed to avoid this phenomenon. The dot pattern method, however, has not been designed to avoid the moiré patterns. In this paper, a new dot pattern method is proposed to avoid the moiré patterns with a good image quality. Image quality and the resistance to moiré effects of the proposed halftoning method are analyzed and compared with the conventional halftoning method by Fourier spectral analysis.

Introduction

The appearance of moiré patterns in the reconstruction of optically scanned halftone images[1] is a severe problem with the high-fidelity reconstruction[2]. The moiré patterns appear whenever a sampling frequency of the scanner is close to intensive spatial frequencies of the halftone image. To avoid the appearance of moiré patterns, various dither methods such as error diffusion[1] and blue noise mask[3] have been proposed. These methods produce dot patterns without intensive frequencies and with blue noise characteristics. The blue noise characteristics in spatial frequency domain correspond to visually preferred patterns without the low frequency graininess in the image domain.

To print small digital images, such as digitized TV images, a dot pattern method is often used to generate halftone images. However, the conventional dot pattern method has not been designed to avoid the moiré patterns. In this paper, we propose a new dot pattern method using pseudo-random dot patterns with a good image quality and without moiré effects.

Dot Pattern Methods

When the dot pattern method is applied to an original digital image, one pixel in the original digital image corresponds to the dot pattern in the halftone image. The dots pattern is decided according to the gray level of the pixel in the original image. Figures 1 show examples of the dot pattern methods with 4×4 dots pattern.

In the conventional dot pattern method, a dot in the dot pattern is generated where the gray level of the pixel in the original digital image is over the corresponding level of threshold-data matrix, as shown in Figure 1(a). In this study, we use Bayer matrix. A gray scale ramp of this method is shown in Figure 2(a).

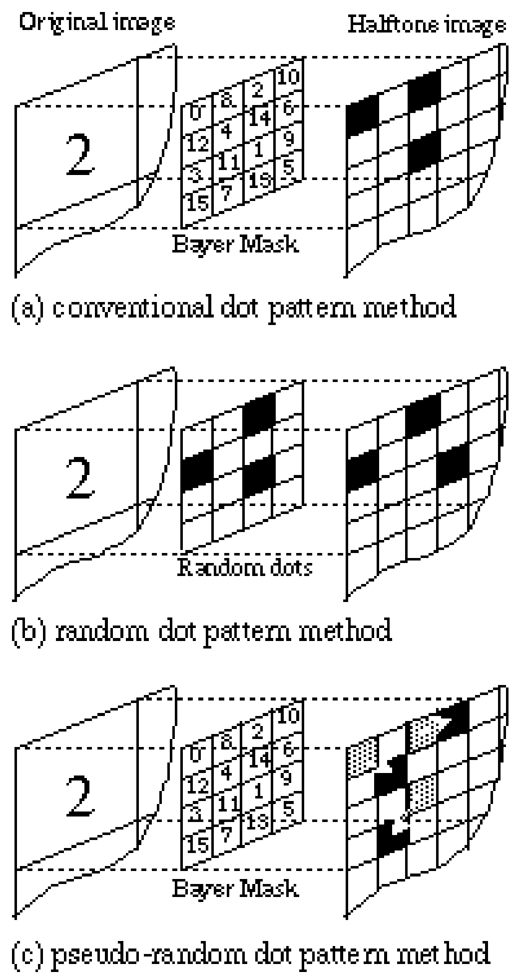

Figure 1. Dot pattern methods

In the random dot pattern method, the gray levels of the original digital image are linearly mapped to the num-

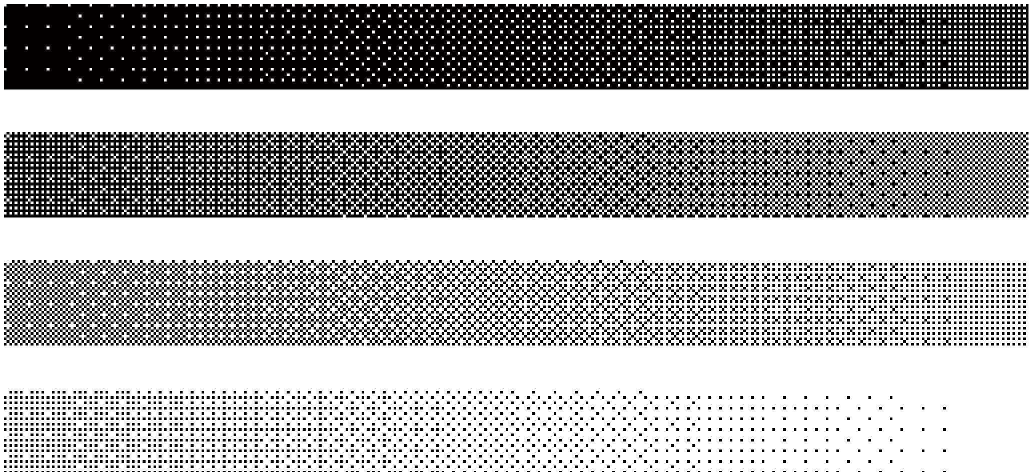

Figure 2(a). Gray Scale Ramp by Conventional dot pattern method

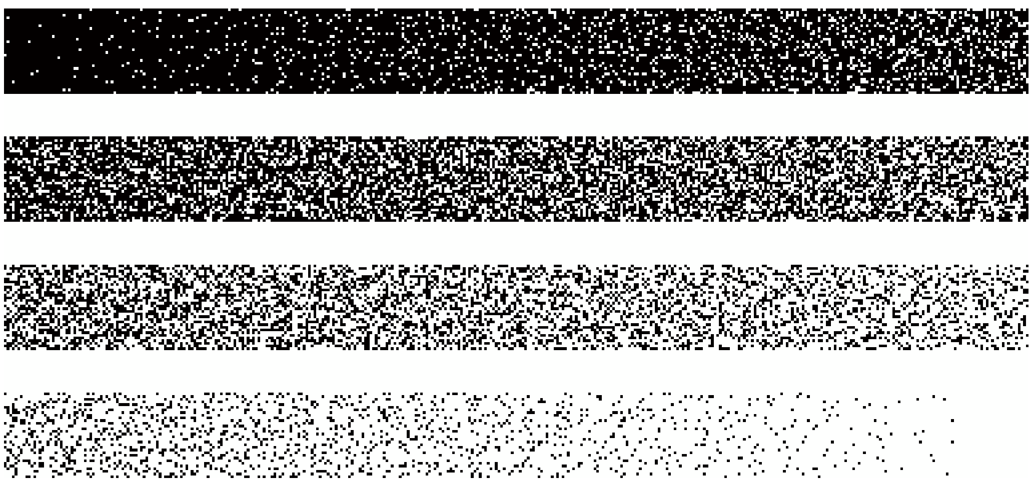

Figure 2(b). Gray Scale Ramp by Random dot pattern method

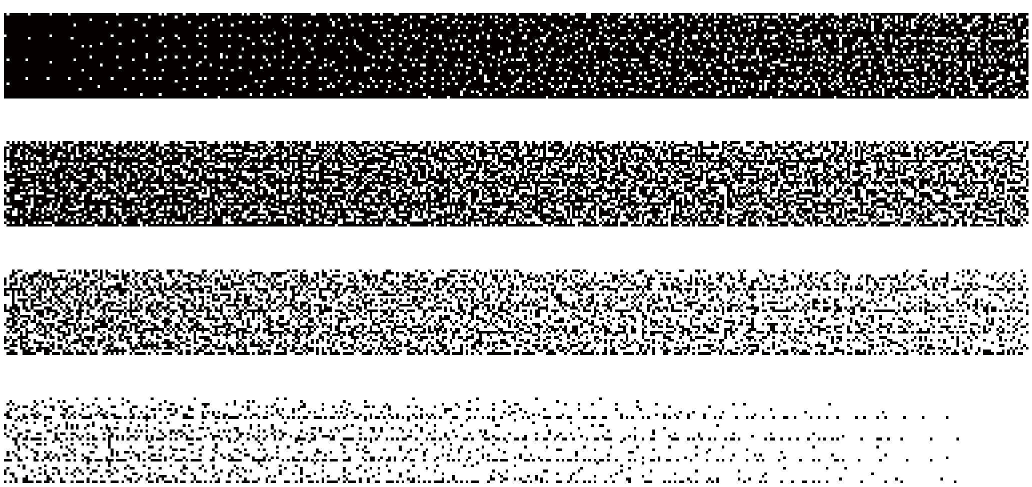

Figure 2(c). Gray Scale Ramp by Pseudo-Random dot pattern method ber of dots in a dot pattern, as shown in Figure 1(b). Each dot is randomly plotted on dot pattern to avoid moiré effects in scanning. A gray scale ramp of this method is shown in Figure 2(b).

The pseudo-random dot pattern method is a combination method with two former methods as shown in Figure 1(c). We first create a fixed dot pattern of corresponding gray level using the conventional dot pattern method mentioned above. Then, we move each dot in a randomly decided direction to a new position within its 8-neighbors to create the pseudo-random pattern. A gray scale ramp of this method is shown in Figure 2(c).

Spectral Characteristics

Figures 3(a),(b),(c) show radial average power spectrums as a function of radial frequencies of the halftone images in the conventional, random, pseudo-random dot pattern methods, respectively. In each method, seven original images with a level of 32, 64, 96, 128, 192 or 224, respectively, and have 16×16 pixels are used, and 8×8 dot patterns are used in halftoning. We suppose that R is the length and width of the halftone image. In Figure 3(a) for the conventional method, there are intensive frequencies. In this case, it is clear that the moiré pattern will appear if the halftone image is scanned with a sampling pitch close to one of the intensive frequencies. In Figure 3(b) for the random method, there are no intensive frequencies. So, the moiré pattern will not appear in any case. However, graininess will appear since the low-frequency components are relatively high. In Figure 3(c) for the proposed method, there are no intensive frequency, and the low-frequency components are lower than those of the random method. We can say that the power spectrums of the proposed method have a blue noise characteristic. These experimental results show that the proposed method can produce the good quality halftone images without moiré patterns.

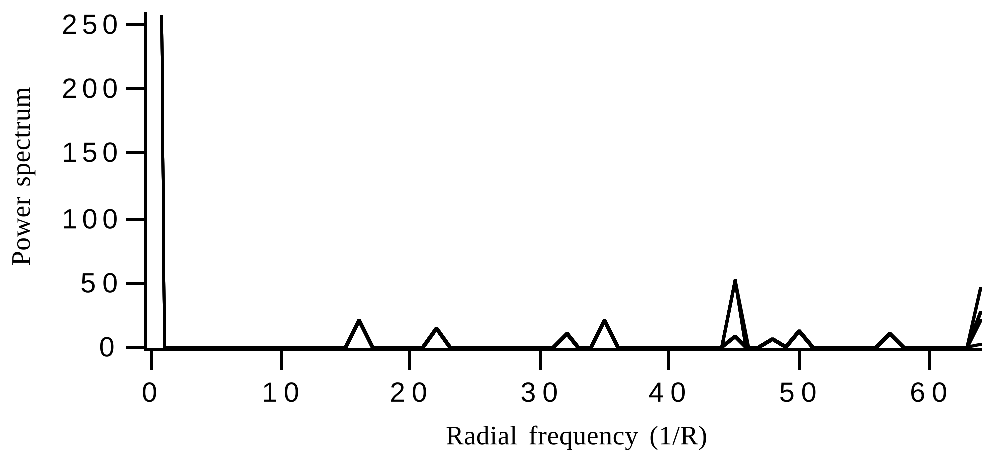

Figure 3(a). Radial Spectra for the Conventional dot pattern method

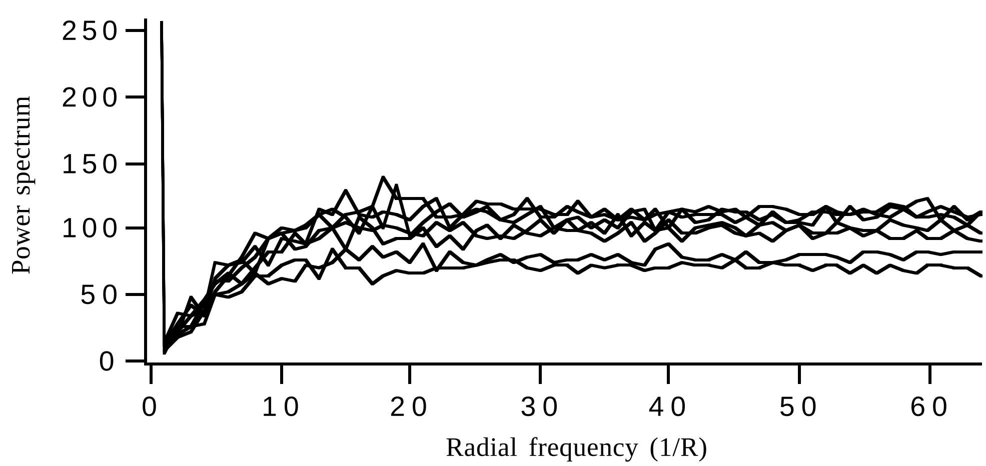

Figure 3(b). Radial Spectra for the Random dot pattern method

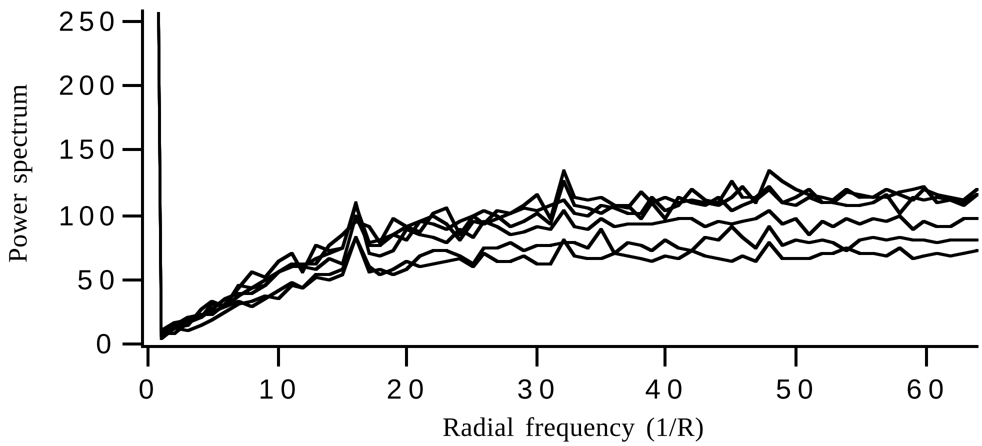

Figure 3(c). Radial Spectra for the Pseudo-Random dot pattern method

Conclusion

The reconstructed images with the conventional dot pattern method have no any immunity to moiré patterns but have visually good image quality. The reconstructed images with the random dot pattern method have spectral characteristic as white noise and have strong visible noise patterns but have good immunity to moiré effects. The reconstructed images with the proposed method not only have immunity to moiré effects but also have a visually good image quality.

Experimental results for various kinds of images will be shown at the conference.

References

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3. T. Mitsa and K. J. Parker, "Digital halftoning technique using a blue-noise mask," *J. Opt. Soc. Am*. A **9**, 1920-1929 (1992).

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