# GENERATION OF HALFTONE-DOT-LIKE IMAGE USING INVERSE FILTERING AND MINIMUM/MAXIMUM VALUES OF ADJACENT PIXELS

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ABSTRACT. *In the past, a number of visual effect methods for generating a halftone image from a photographic image have been proposed. In this paper, we propose a visual effect method for generating a halftone-dot-like image from the photographic image. Our method is executed by an iterative calculation using inverse filtering and minimum/maximum values of adjacent pixels. Our method is simpler than conventional methods for generating the halftone images, and can generate images with different patterns while preserving edges compared with conventional methods. Furthermore, our method can be used as unsharp mask by decreasing the value of the parameter of inverse filtering. To verify the visual effects of our method, we conduct an experiment with changing the value of the parameters and an experiment using various photographic images. As a result of the experiments, we found that our method can generate the halftone-dot-like image automatically, and clarified how to generate the halftone-dot-like patterns according to the value of the parameters in our method.*

**Keywords:** Visual effect, Halftone dot, Inverse filtering, Unsharp mask

1. **Introduction.** Visual effects are to process a real video image by computer graphics or synthetic processing, and are used to realize screen effects in a video and a television that cannot be seen actually. Recently, many software for visual effects that can be easily processed on a personal computer and a mobile terminal have appeared, and many users use these software to process a photographic image and a photographic video. For example, when the photographic image is processed using such software, the photographic image is converted into a pencil-drawing-like image [1, 2], a watercolor-painting-like image [3], an oil-painting-like image [4], and a charcoal-drawing-like image [5].

This paper proposes a visual effect method for generating a halftone-dot-like image from the photographic image. A halftone dot is an image with a reticulated dot representing the luminance value, and the halftone-dot-like image imitates the halftone dot. There is a halftone image similar to the halftone-dot-like image. A density pattern method, a dither method, and an error diffusion method are well known as methods for generating the halftone image [6]. Blurring of edges is known as a problem of these halftone methods. Therefore, as a halftone method to emphasize edges, a method improving the error diffusion method has been proposed [7, 8, 9]. Eschbach and Knox [7] modified the error diffusion method by introducing an input-dependent threshold into the process, Kang et al. [8] used weighting function that is composed of the magnitude and the sign of the

local average of surrounding pixels, and Li [9] presented the method to stop the diffusion at edge pixels and turn the support of the diffusion kernel to match the local edge orientation. The proposed method is executed by an iterative calculation using inverse filtering [10, 11] and minimum/maximum values of adjacent pixels. The proposed method is simpler than the halftone methods, and can preserve edges. The proposed method also can be used as unsharp mask by decreasing the value of the parameter of inverse filtering. To verify the visual effects of the proposed method, experiments with changing the value of the parameters in the proposed method are conducted. Also, experiments using various photographic images are conducted.

The rest of this paper is organized as follows. Section 2 describes the proposed method using inverse filtering and minimum/maximum values of adjacent pixels. Section 3 shows experimental results, and reveals that the proposed method can generate the halftone-dot-like image from various photographic images, and becomes unsharp mask by decreasing the value of the parameter. Finally, Section 4 concludes this paper.

2. **Proposed Method.** The halftone-dot-like image is generated by performing two processes. The first process converts the pixel value of the photographic image to the minimum or maximum value of adjacent pixels. The second process restores the converted image to the photographic image by inverse filtering. The restored image includes a restoration error. The restoration error is emphasized by repeating the two processes, and the halftone-dot-like image is generated. A flow chart of the proposed method is shown in Figure 1.
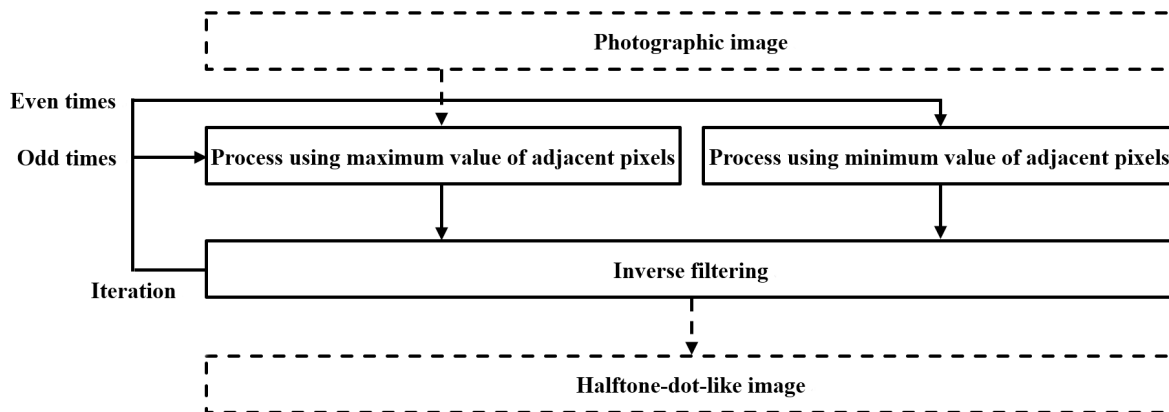


FIGURE 1. Flow chart of the proposed method

2.1. **Process using minimum/maximum value of adjacent pixels.** Let input pixel values (Red, Green, and Blue) on coordinates $(i, j)$ of the photographic image be $f_{R,i,j}$, $f_{G,i,j}$, and $f_{B,i,j}$ $(i = 1, 2, \ldots, I; \ j = 1, 2, \ldots, J)$, respectively. The pixel values $f_{R,i,j}$, $f_{G,i,j}$, and $f_{B,i,j}$ have value of 256 gradation from 0 to 255. Let pixel values at the $t$-th $(t = 1, 2, \ldots, T)$ iteration number be $f_{R,i,j}^{(t)}$, $f_{G,i,j}^{(t)}$, and $f_{B,i,j}^{(t)}$, respectively.

The first process converts the pixel values of the photographic image to the minimum or maximum value of adjacent pixels. When $t$ is an odd number, $f_{R,i,j}^{(t)}$ is replaced with the maximum value including its adjacent pixels. On the other hand, when $t$ is an even number, $f_{R,i,j}^{(t)}$ is replaced with the minimum value including its adjacent pixels. By using minimum value or maximum value, the image can converge to binary values by the iterative calculation, and edges of the image can be preserved. And, by alternating minimum and maximum values, the iterative calculation prevents the pixel value $f_{R,i,j}^{(t)}$ of the image from converging to one side of white or black. $f_{G,i,j}^{(t)}$ and $f_{B,i,j}^{(t)}$ are also processed in the same way. Let the converted pixels be $g_{R,i,j}^{(t)}$, $g_{G,i,j}^{(t)}$, and $g_{B,i,j}^{(t)}$.

2.2. **Inverse filtering.** The second process computes the pixel values $h_{R,i,j}^{(t)}$, $h_{G,i,j}^{(t)}$, and $h_{B,i,j}^{(t)}$ by inverse filtering as

$$h_{R,i,j}^{(t)} = a \left( f_{R,i,j}^{(t)} - g_{R,i,j}^{(t)} \right) + f_{R,i,j} \tag{1}$$

$$h_{G,i,j}^{(t)} = a \left( f_{G,i,j}^{(t)} - g_{G,i,j}^{(t)} \right) + f_{G,i,j} \tag{2}$$

$$h_{B,i,j}^{(t)} = a \left( f_{B,i,j}^{(t)} - g_{B,i,j}^{(t)} \right) + f_{B,i,j} \tag{3}$$

where $a$ is a positive constant. Let $h_{R,i,j}^{(t)}$, $h_{G,i,j}^{(t)}$, and $h_{B,i,j}^{(t)}$ be $f_{R,i,j}^{(t+1)}$, $f_{G,i,j}^{(t+1)}$, and $f_{B,i,j}^{(t+1)}$, respectively, and return to the first process.

The halftone-dot-like image is generated by repeating the iteration calculation $T$ times. It should be noted that, if the value of $a$ is small, the proposed method operates as unsharp mask. By decreasing the value of $a$, it is possible to prevent the occurrence of the fine halftone-dot-like patterns, so that it becomes unsharp mask.

3. **Experiments.** First, experiments with changing the value of the parameters are conducted using the Lenna image (Figure 2). Next, experiments using various photographic images are conducted. All experiments are conducted using the photographic images with $256 * 256$ pixel size and 256 graduation.



FIGURE 2. Lenna image

3.1. **Experiments with changing the parameters.** The halftone-dot-like images generated by changing the value of the iterative number $T$ are visually confirmed using the Lenna image. The value of $T$ is set to 2, 10, 30, 50. The value of $a$ is set to 2.0. The results of the experiment are shown in Figure 3. As the value of $T$ is larger, the halftone-dot-like patterns become clearer. The halftone-dot-like images do not change when the value of $T$ is around 50. Thus, the value of $T$ should be around 50.



(a) $T = 2$      (b) $T = 10$      (c) $T = 30$      (d) $T = 50$

FIGURE 3. Halftone-dot-like images with changing $T$

The halftone-dot-like images generated by changing the value of the parameter $a$ are visually confirmed using the Lenna image. The value of $a$ is set to 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, 4.0, and 6.0. The value of $T$ is set to 50. The results of the experiment are shown in Figure 4. The visual effects are examined for the halftone-dot-like images when $a$ is 1.0 or more (Figures 4(e), 4(f), 4(g), and 4(h)). As the value of $a$ is larger, the halftone-dot-like patterns become clearer. However, as the value of $a$ is larger, the saturation of the halftone-dot-like images decreases. Thus, the value of $a$ should be around 2.0 when generating the halftone-dot-like images. On the other hand, the visual effects are examined for the images of unsharp mask when $a$ is smaller than 1.0 (Figures 4(a), 4(b), 4(c), and 4(d)). When the value of $a$ is smaller than 1.0, the generated images are cleared with the emphasized edges. As the value of $a$ is smaller, the fine edge emphasis is reduced. As the value of $a$ is 0.8, the halftone-dot-like patterns are generated slightly in the image. Thus, the value of $a$ should be around 0.4 when using the proposed method as unsharp mask.



(a) $a = 0.2$    (b) $a = 0.4$    (c) $a = 0.6$    (d) $a = 0.8$

(e) $a = 1.0$    (f) $a = 2.0$    (g) $a = 4.0$    (h) $a = 6.0$

FIGURE 4. Halftone-dot-like images with changing $a$

3.2. **Experiments using various images.** The proposed method is applied to eight additional photographic images shown in Figure 5. The values of $T$ and $a$ are set to 50 and 2.0, respectively. The results of the experiment are shown in Figure 6. The halftone-dot-like patterns are automatically generated throughout entire regions for all halftone-dot-like images, and all halftone-dot-like images are preserved edges. However, the halftone-dot-like patterns are less likely to occur in a region that is dark and has small change in the pixel value, for example, in the black suit part of Figure 6(c). The reason is that there is no factor emphasized as the halftone-dot-like patterns by the proposed method without change of the pixel value. Therefore, it is conceivable to add noise to the region that is dark and small change in the pixel value. Also, the halftone-dot-like patterns are less likely to occur in a fine texture region, for example, in Figure 6(f). The reason is that the patterns of the fine texture region are finer than the halftone-dot-like patterns. Therefore, it is conceivable to smooth the fine texture region in advance.

(a) Airplane          (b) Balloon          (c) Couple          (d) Earth

(e) Girl          (f) Mandrill          (g) Parrots          (h) Pepper

FIGURE 5. Various photographic images



(a) Airplane          (b) Balloon          (c) Couple          (d) Earth

(e) Girl          (f) Mandrill          (g) Parrots          (h) Pepper

FIGURE 6. Halftone-dot-like images for various photographic images

4. **Conclusions.** This paper proposed a visual effect method for generating the halftone-dot-like image from a photographic image. The proposed method was performed by two processes. The first process converted the pixel value of the photographic image to the minimum or maximum value of adjacent pixels. The second process restored the converted image to the photographic image by inverse filtering. To verify the visual effects of the proposed method, experiments with changing the value of the parameters were conducted.

As a result of the experiments, the proposed method could generate the halftone-dot-like image automatically, and preserve edges. Furthermore, the proposed method could be used as unsharp mask by decreasing the value of the parameter of inverse filtering. However, the halftone-dot-like patterns were less likely to occur in a region that is dark and has small change in the pixel value and a fine texture region.

Further study is to improve the proposed method so that the halftone-dot-like patterns can be generated in the region where the halftone-dot-like patterns are difficult to occur. Another future challenge is to apply the proposed method to a video.

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