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GENERATION OF ZEBRA-PATTERN IMAGES USING SMOOTHING FILTER IN CONSIDERATION OF SCANNING ORDER AND UNSHARP MASK

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Abstract. *We propose a non-photorealistic rendering method for generating zebra-pattern images from gray-scale photographic images. Zebra-pattern images are a representation of photographic images using zebra patterns that are largely configured in one direction. Our method is executed by two processing: the first processing uses smoothing filter in consideration of a scanning order, and the second processing uses unsharp mask. Our method has features that the processing is simple, zebra patterns can be automatically generated, and can control the direction in which zebra patterns are generated. To validate the effectiveness of our method, experiments using various photographic images were conducted. Results show that our method can practically realize these features.*
Keywords: Non-photorealistic rendering, Zebra pattern, Smoothing filter, Scanning order, Unsharp mask

1. **Introduction.** In recent years, mobile terminals such as smartphones and tablets have become widespread, and users can easily take photographic images and videos. Furthermore, many applications have been provided that can convert photographic images for easy viewing, can convert photographic images to non-photorealistic images such as oil paintings and pencil drawings, or can add playful attitudes such as attaching cat's ears to person's heads. Methods of converting photographic images to non-photorealistic images are called non-photorealistic rendering (NPR), and researches on NPR have been actively conducted since the early 1990's [1, 2, 3, 4, 5, 6, 7]. Recently, many researches on NPR using various patterns appearing in nature have also been conducted. For example, oil-film images [8], reaction-diffusion images [9], cell images [10], and concrete-wall images [11] have been proposed as such NPR in nature. Oil-film images were represented by colorful and smooth curves similar to oil films generated on the surface of glass or water, and were generated using bilateral infra-envelope filter. Reaction-diffusion images were represented by self-organized patterns that were generated by using anisotropic reaction diffusion to deform shape and introducing a flow field to guide pattern arrangement. Cell images were represented by sell patterns that were formed from a cell membrane and a cell nucleus, and were generated using inverse iris filter. Concrete-wall images imitated uneven concrete walls, and were generated using autocorrelation coefficient and inverse filter. As these images that were represented by the patterns in nature will be impressive, more representation methods are required.

In this paper, we focus on zebra pattern shown in Figure 1 as NPR in nature, and propose an NPR method for generating zebra-pattern images from gray-scale photographic images. Zebra-pattern images are a representation of photographic images using zebra patterns. Zebra patterns consist of white and black, and are largely configured in one

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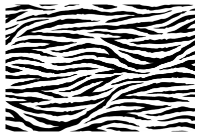


FIGURE 1. Zebra pattern

direction. The proposed method is executed by a processing using smoothing filter in consideration of a scanning order and unsharp mask. The proposed method is simple and easy to implement, can automatically generate zebra patterns according to the density and contour of photographic images, and can control the direction in which zebra patterns are generated. A method for generating ripple images similar to zebra-pattern images has also been proposed [12]. The proposed method can generate zebra patterns on the entire image, although there are areas where it is difficult for ripple patterns to be generated by the conventional method [12]. To visually verify the effectiveness of the proposed method, experiment using Lenna image was conducted to investigate the changes of zebra patterns generated by varying the values of the parameters in the proposed method and the scanning order. In addition, the proposed method was applied to various images. As a result of the experiments, it is revealed that zebra patterns can be automatically generated on the whole image, and the direction of zebra pattern can be controlled.

This paper is organized as follows: the second section describes the proposed method for generating zebra-pattern images, the third section shows experimental results and reveals the effectiveness of the proposed method, and the conclusion of this paper is given in the fourth section.

2. **Proposed Method.** The proposed method generates zebra-pattern images from gray-scale photographic images. The proposed method is executed in two steps. In the first step, processing using smoothing filter in consideration of the scanning order is performed. In the second step, processing using unsharp mask is performed. A flow chart of the proposed method is shown in Figure 2. It turns out that the proposed method does not use particularly difficult processing.

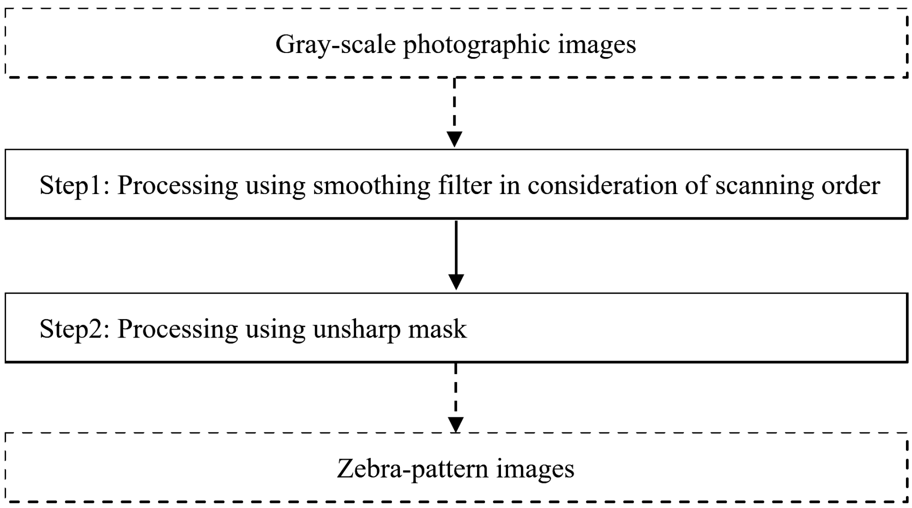


FIGURE 2. Flow chart of the proposed method

Details of the steps in Figure 2 are explained below.

Step 0: Let the input pixel values on coordinates (i, j) of a gray-scale photographic image be $f_{i,j}$. The pixel values $f_{i,j}$ have value of 256 gradation from 0 to 255. In the following processing, by adding pixels around photographic image, the influence of the periphery of photographic image is eliminated.

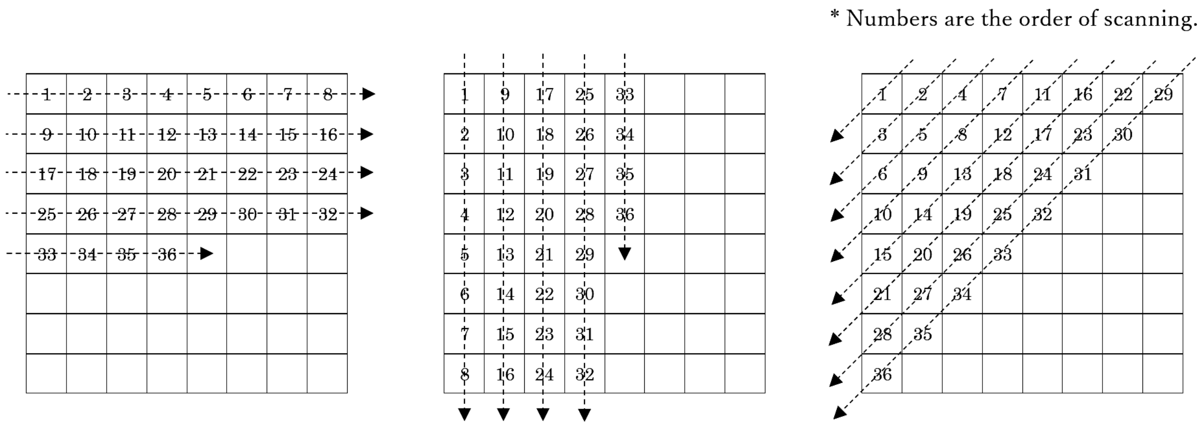
Step 1: The pixel values $f_{i,j}^{(t)}$ are smoothed using the pixel values $s_{i,j}^{(t)}$ in the window of W pixels, where t $(= 0, 1, 2, \ldots)$ is the iteration number and $f_{i,j}^{(0)} = f_{i,j}$. The pixel values $s_{i,j}^{(t)}$ are initialized to $f_{i,j}^{(t-1)}$, and are updated by the pixel value $f_{i,j}^{(t)}$ that are sequentially calculated by Equation (1). The smoothed pixel values $f_{i,j}^{(t)}$ are calculated as follows.

$$f_{i,j}^{(t)} = \frac{1}{2W+1} \sum_{k=-W}^{W} \sum_{l=-W}^{W} s_{i+k,j+l}^{(t)} \tag{1}$$

$$s_{i,j}^{(t)} = f_{i,j}^{(t)} \tag{2}$$

where (k, l) is a plurality of spatial coordinates of the pixels included in the range of $\pm W$ around the spatial coordinate (i, j). The processing of Step 1 is repeated T_1 times.

In the following experiment, three scanning types shown in Figure 3 were used in the order for updating the pixel values $s_{i,j}^{(t)}$ in Equation (1). Type 1 (Figure 3(a)) scans in the horizontal direction, and as a result, horizontal zebra patterns are generated. Type 2 (Figure 3(b)) scans in the vertical direction, and as a result, vertical zebra patterns are generated. Type 3 (Figure 3(c)) scans in the oblique direction, and as a result, oblique zebra patterns are generated.



(a) Type 1 (b) Type 2 (c) Type 3

Figure 3. Scanning types

Step 2: Let the pixel values $f_{i,j}^{(T_1)}$ be $g_{i,j}^{(0)}$. The pixel values $g_{i,j}^{(t)}$ are calculated using unsharp mask as follows.

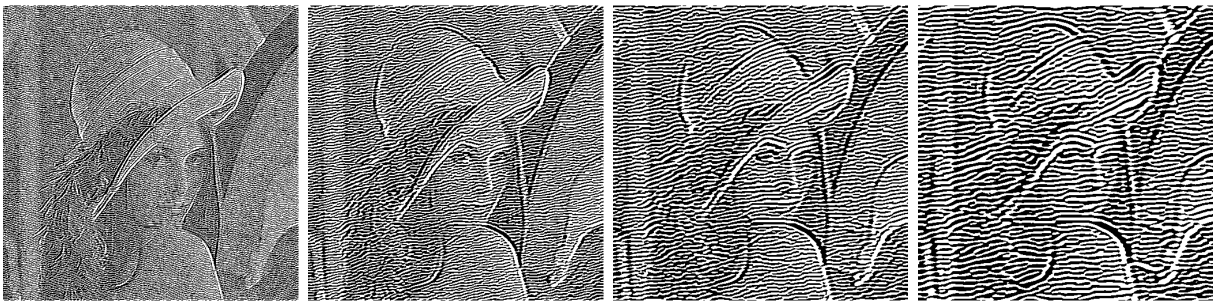
$$g_{i,j}^{(t)} = g_{i,j}^{(t-1)} - \frac{1}{2W+1} \sum_{k=-W}^{W} \sum_{l=-W}^{W} g_{i+k,j+l}^{(t-1)} \tag{3}$$

In case $g_{i,j}^{(t)}$ is less than 0, then $g_{i,j}^{(t)}$ must be set to 0. In case $g_{i,j}^{(t)}$ is greater than 255, then $g_{i,j}^{(t)}$ must be set to 255. The processing of Step 2 is repeated T_2 times. An image composed of pixel values $g_{i,j}^{(T_2)}$ is a zebra-pattern image.

3. **Experiments.** Two experiments were conducted mainly. First, the proposed method was applied to Lenna image shown in Figure 4. The changes in appearance to zebra-pattern images were visually assessed as the values of the parameters and the scanning type were varied. Next, the proposed method was applied to various images. Unless otherwise specified, in the experiments, the values of W, T_1 and T_2 were respectively set to 3, 6 and 40, and Type 1 was used as the scanning type. The reason for setting the values of the parameters as described above is that zebra patterns can be grasped visually well and it is easy to recall photographic images. And, the reason for using Type 1 is that horizontal zebra patterns are the basis of the proposed method. All images used in the experiments were $512 * 512$ pixels and 256 gradation.

FIGURE 4. Lenna image

3.1. **Experiments with varying parameters and scanning types.** Zebra-pattern images by varying the value of the window size W were confirmed visually using Lenna image. The value of W was set to 1, 2, 3 and 4. The results of the experiment are shown in Figure 5. As the value of W was larger, the size of zebra patterns became wider and it became harder to see original photographic image.



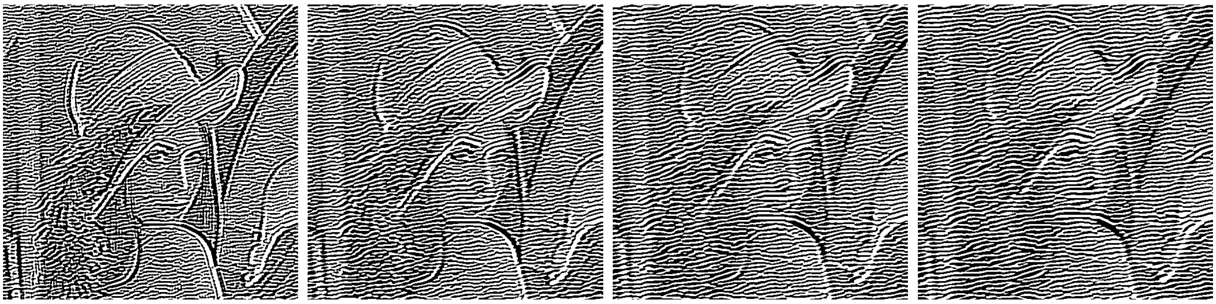
(a) $W = 1$ (b) $W = 2$ (c) $W = 3$ (d) $W = 4$

FIGURE 5. Zebra-pattern images for $W = 1, 2, 3$ and 4

Zebra-pattern images by varying the value of the iteration number T_1 were confirmed visually using Lenna image. The value of T_1 was set to 3, 6, 9 and 12. The results of the experiment are shown in Figure 6. As the value of T_1 was larger, the shape of zebra patterns became smoother and it became harder to see original photographic image.

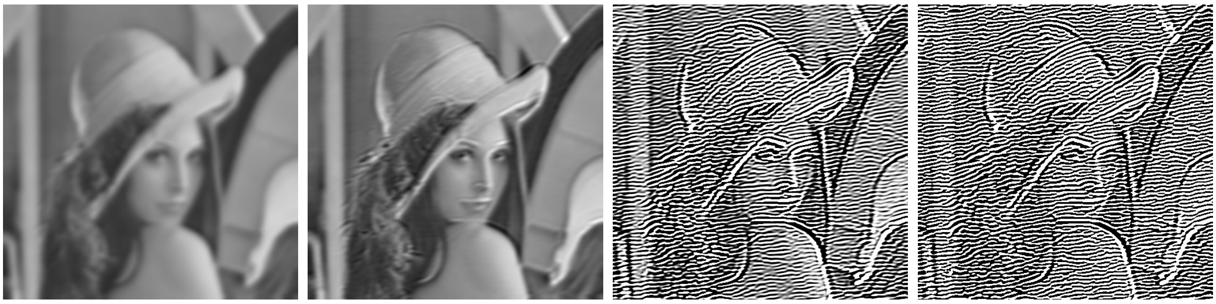
Zebra-pattern images by varying the value of the iteration number T_2 were confirmed visually using Lenna image. The value of T_2 was set to 5, 10, 20 and 40. The results of the experiment are shown in Figure 7. As the value of T_2 was larger, the shape of zebra patterns became finer.

Zebra-pattern images by varying the scanning type were confirmed visually using Lenna image. Type 1, Type 2 and Type 3 were used as the scanning type. The results of the experiment are shown in Figure 8. Horizontal, vertical and oblique zebra patterns were



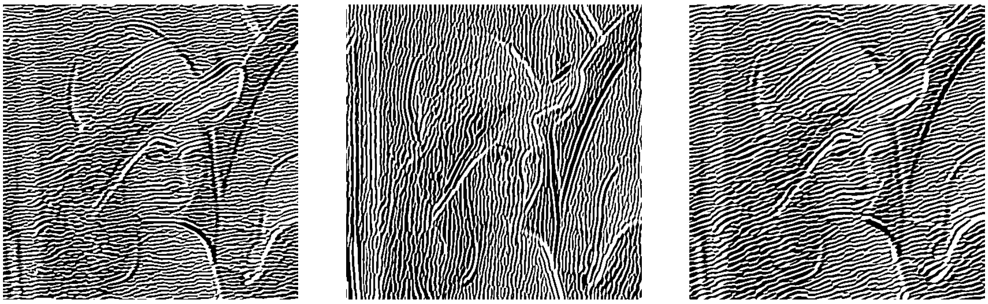
(a) $T_1 = 3$ (b) $T_1 = 6$ (c) $T_1 = 9$ (d) $T_1 = 12$

FIGURE 6. Zebra-pattern images for $T_1 = 3, 6, 9$ and 12



(a) $T_2 = 5$ (b) $T_2 = 10$ (c) $T_2 = 20$ (d) $T_2 = 40$

FIGURE 7. Zebra-pattern images for $T_2 = 5, 10, 20$ and 40



(a) Type 1 (b) Type 2 (c) Type 3

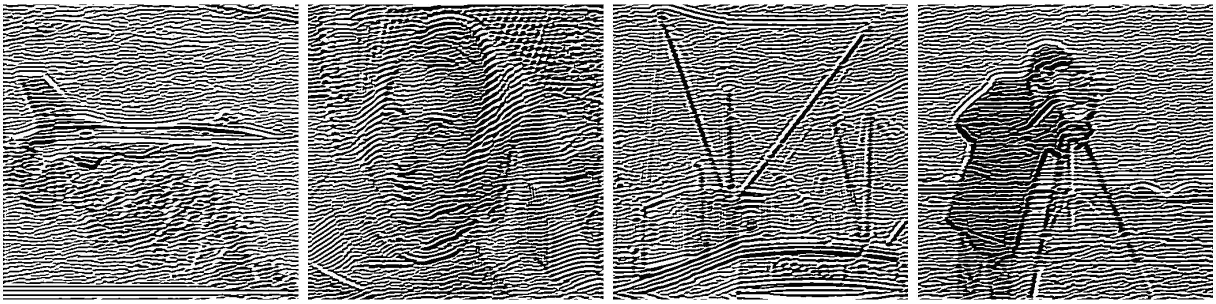
FIGURE 8. Zebra-pattern images for three scanning types

generated in Type 1, Type 2 and Type 3, respectively. In all types, setting the values of W, T_1 and T_2 to 3, 6 and 40, respectively, successfully generated zebra patterns.

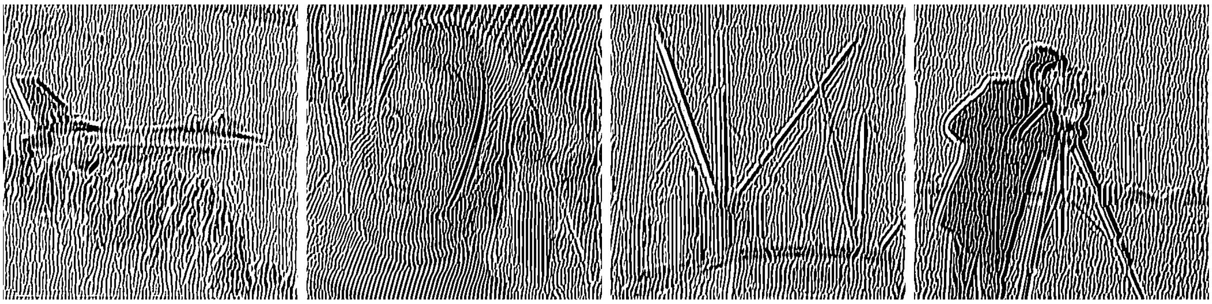
3.2. **Experiment using various photographic images.** The proposed method was applied to four photographic images shown in Figure 9. Zebra-pattern images by varying the scanning type were confirmed visually. The results are shown in Figure 10. The upper, middle and lower parts of Figure 10 are for Type 1, Type 2 and Type 3, respectively. In all cases, zebra patterns could be automatically generated according to the density and contour of photographic images, and could control the direction in which zebra patterns are generated.

4. **Conclusions.** This paper proposed an NPR method for generating zebra-pattern images from gray-scale photographic images by processing using smoothing filter in consideration of a scanning order and unsharp mask. The proposed method had features that the processing is simple, zebra patterns can be automatically generated, and can control the direction in which zebra patterns are generated. In the experiments using Lenna image

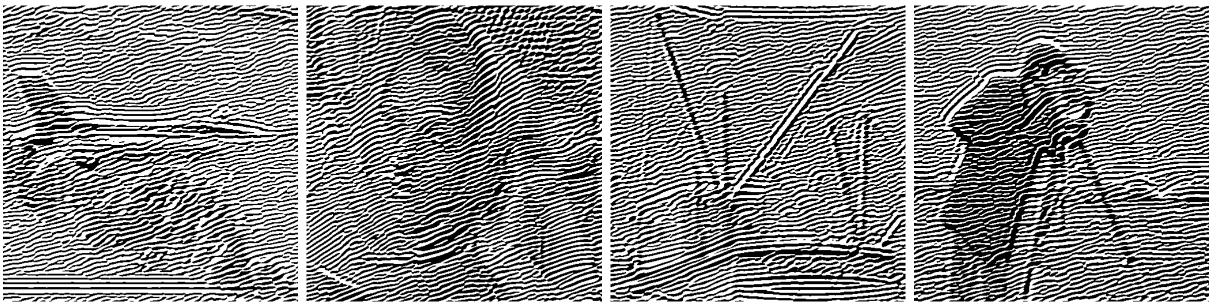
FIGURE 9. Various photographic images



(a) Type 1



(b) Type 2



(c) Type 3

FIGURE 10. Zebra-pattern images

and other photographic images, it was clarified that the proposed method can practically realize these features.

A subject for future study is to expand the proposed method for application to color photographic images and videos.

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