Generation of Arbitrarily-Oriented Ripple Images Using Smoothing Filter with Translated Window

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Abstract

A non-photorealistic rendering method for automatically generating ripple images from photographic images using region-division smoothing filter has been proposed. Ripple patterns are composed of continuous lines with fluctuations, and ripple images are expressed by superimposing ripple patterns on photographic images. To generate ripple images that give different visual effects, this paper develops a method for generating ripple patterns with a texture different from the conventional method. The proposed method is executed by an iterative calculation using smoothing filter with the translated window. In the proposed method, the orientation of ripple patterns can be arbitrarily controlled by changing the amount of translation of the window used in smoothing filter. To verify the effectiveness of the proposed method, an experiment using various photographic images was conducted. Additionally, an experiment to visually examine how ripple patterns generated by changing the values of the parameters in the proposed method change.

Keywords: Non-photorealistic rendering, Ripple pattern, Smoothing filter, Translation of window, Arbitrary orientation

1. Introduction

In contrast to traditional computer graphics which focuses on photorealism, non-photorealistic rendering[1][2] which focuses on enabling different styles of expression in digital art is attracting attention. Non-photorealistic rendering often converts photographic images, videos, and three-dimensional data into art styles that imitate paintings, drawings, and cartoons. Recently, many studies have been conducted on non-photorealistic rendering to convert to unprecedented art styles such as cell-like images[3], moire-like images[4], and ripple images[5]. Cell-like patterns are composed of cell membrane and cell nucleus, and then cell-like images are overlaid with cell-like patterns on photographic images. Moire-like images are non-realistic images obtained by overlaying moire patterns on photographic images. Ripple images are non-realistic images expressing photographic images by ripple patterns, and ripple patterns are generated along the edges of photographic images.

This paper focuses on ripple images and proposes a method for generating ripple patterns with a texture different from the conventional method. The proposed method is executed by an iterative calculation using smoothing filter with the translated window. A feature of the proposed method is that the orientation of ripple patterns can be arbitrarily controlled by changing the amount of translation of the window. In the conventional method, for example, when ripple patterns in the orientation rotated by $\pi/4$ radian are generated, ripple patterns are expressed as being slightly bent, but the proposed method does not do so. An experiment using several photographic images show that the proposed method can generate ripple patterns on the entire image. Additionally, an experiment with changing the amount of R6translation of the window show that the proposed method can control the orientation of ripple patterns.

2. Proposed Method

The proposed method is largely executed in three steps. Step 1 is to apply smoothing filter. As a result, the finally generated ripple patterns can be expressed smoothly and clearly. Step 2 is to apply smoothing filter with the translated window. Step 3 is to apply inverse filter[6]. Inverse filter restores the image converted in Step 2 to the original image. By repeating the processes of Steps 1 and 2, restoration errors are accumulated, and ripple images are generated. A flow chart of the proposed method is shown in Fig. 1.

Details of the steps in Fig. 1 are explained below.

Step 0: The input pixel values on coordinates (i,j) of a gray-scale photographic image are defined as $o_{i,j}$. The pixel values $o_{i,j}$ have value of U gradation from 0 to $U-1$. Ripple patterns in the orientation of θ radian are generated.

Step 1: Smoothing filter is applied to the pixel values $o_{i,j}$, and the smoothed pixel values are defined as $f_{i,j}$.

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

where k and l are the positions in the window, and W is the window size.

Step 2: Smoothing filter with the translated window is apply to the pixel values $f^{(t-1)}_{i,j}$, and the smoothed pixel values are defined as $g^{(t-1)}_{i,j}$, where t is the iteration number and $f^{(0)}_{i,j} = f_{i,j}$.

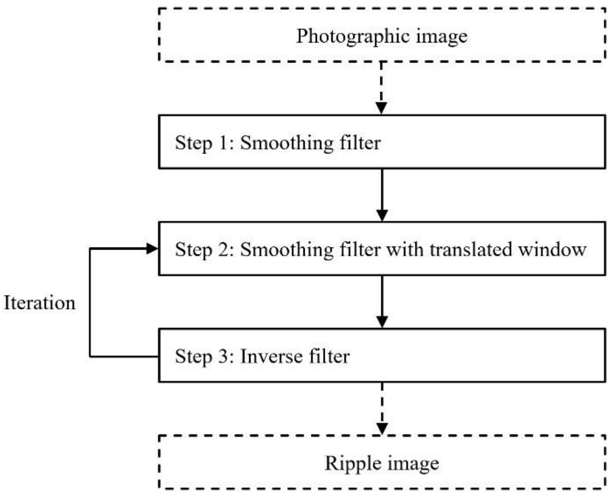


Fig.1. Flow chart of the proposed method

$$g^{(t)}_{i,j} = \frac{\sum_{k=-W}^{W}\sum_{l=-W}^{W} f^{(t-1)}_{i,j} o_{i+k+M,j+l+N}}{(2W+1)^2} \quad (2)$$

$$M = \begin{cases} round(\sqrt{2}sin(\theta)) & (t\%2=0) \\ round(\sqrt{2}sin(\theta+\pi)) & (t\%2=1) \end{cases} \quad (3)$$

$$N = \begin{cases} round(\sqrt{2}cos(\theta)) & (t\%2=0) \\ round(\sqrt{2}cos(\theta+\pi)) & (t\%2=1) \end{cases} \quad (4)$$

where % is a modulo operation and round is a function that rounds to an integer.

Step 3: Inverse filter is applied to the pixel values $g^{(t)}_{i,j}$, and the pixel values applied inverse filter are defined as $f^{(t)}_{i,j}$.

$$f^{(t)}_{i,j} = f^{(t-1)}_{i,j} - g^{(t)}_{i,j} + f_{i,j} \quad (5)$$

If $f^{(t)}_{i,j}$ is smaller than 0, then $f^{(t)}_{i,j}$ must be set to 0, and if $f^{(t)}_{i,j}$ is greater than $U-1$, then $f^{(t)}_{i,j}$ must be set to $U-1$.

Steps 1 and 2 are repeated T times. The image composed of the pixel values $f^{(T)}_{i,j}$ is a ripple image.

3. Experiments

Two experiments were conducted. The first experiment visually confirmed ripple patterns generated by changing the values of the parameters in the proposed method using Woman image shown in Fig. 2. The second experiment applied the proposed method to four photographic images shown in Fig. 3. All photographic images used in the experiments were 512 * 512 pixels and 256 gradations.

3.1. *Experiment with changing parameters*

Ripple images generated by changing the iteration number T were confirmed visually. The iteration number T was set to 5, 10, 20, and 30. The parameters W and θ were set to 2 and $\pi/4$, respectively. The results of the

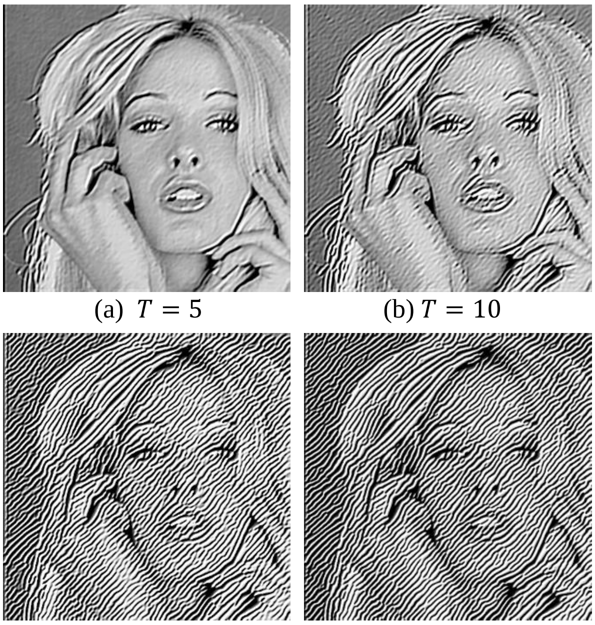
Fig.2. Woman image

Fig.3. Various photographic images

experiment are shown in Fig. 4. As the value of T was larger, ripple patterns became clearer and were expressed finely.

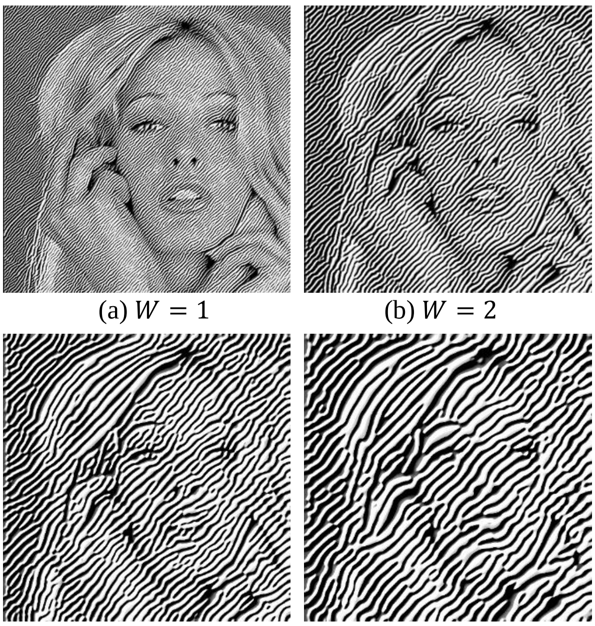
Ripple images generated by changing the window size W were confirmed visually. The window size W was set to 1, 2, 3, and 4. The parameters T and θ were set to 30 and $\pi/4$, respectively. The results of the experiment are shown in Fig. 5. As the value of W was larger, the interval of ripple patterns became wider.

Ripple images generated by changing the orientation θ were confirmed visually. The orientation θ was set to 0, $\pi/6$, $\pi/6$, $\pi/4$, $\pi/3$, $\pi/2$, $2\pi/3$, $3\pi/4$, and



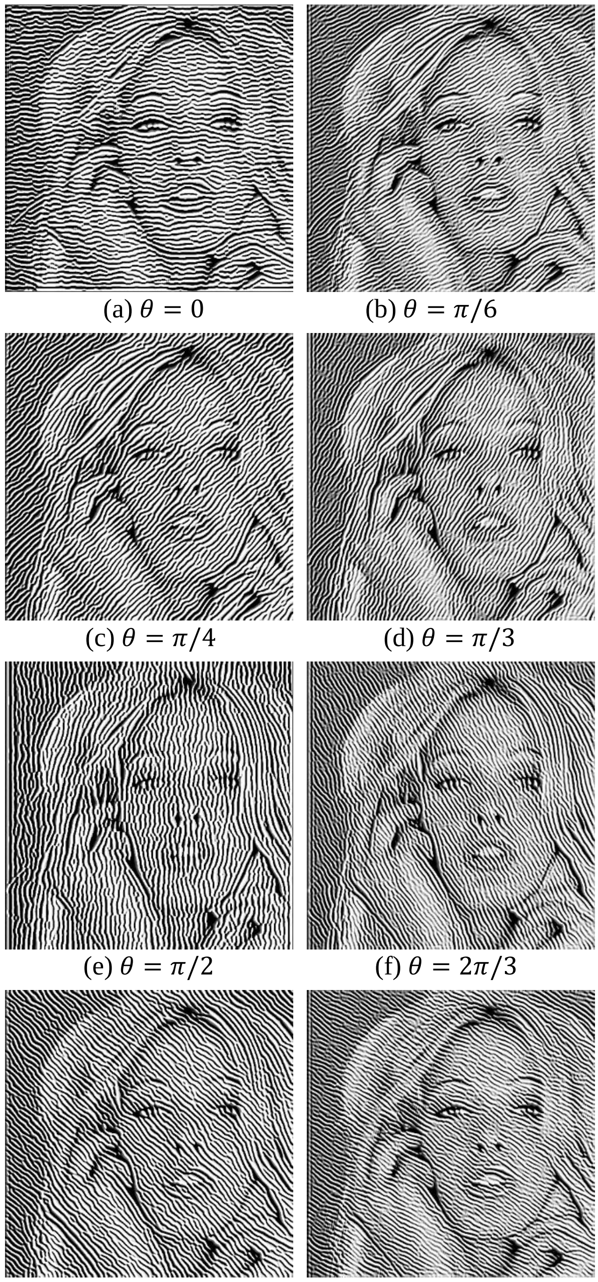
(a) $T = 5$ (b) $T = 10$ (c) $T = 20$ (d) $T = 30$

Fig.4. Ripple images in the case of $T = 5, 10, 20, 30$



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

Fig.5. Ripple images in the case of $W = 1, 2, 3, 4$



(a) $\theta = 0$ (b) $\theta = \pi/6$ (c) $\theta = \pi/4$ (d) $\theta = \pi/3$ (e) $\theta = \pi/2$ (f) $\theta = 2\pi/3$ (g) $\theta = 3\pi/4$ (h) $\theta = 5\pi/6$

Fig.6. Ripple images in the case of $\theta = 0, \pi/6, \pi/4, \pi/3, \pi/2, 2\pi/3, 3\pi/4, 5\pi/6$

$5\pi/6$. The parameters T and W were set to 30 and 2, respectively. The results of the experiment are shown in Fig. 6. For example, ripple patterns occur in the horizontal orientation when θ was 0, and ripple patterns occur in the vertical orientation when θ was $\pi/2$. By changing the value of θ, the orientation of ripple patterns could be controlled.

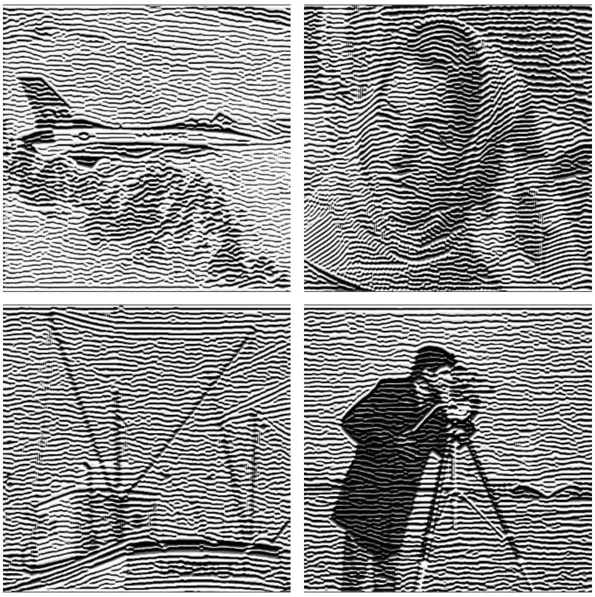


Fig.7. Various ripple images in the case of $\theta = 0$

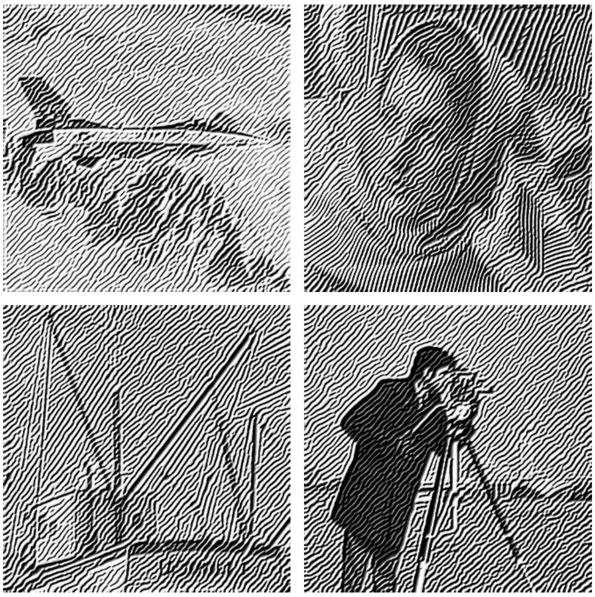


Fig.8. Various ripple images in the case of $\theta = \pi/4$

3.2. *Experiment using various photographic images*

The proposed method was applied to four photographic images shown in Fig. 3. The parameters T and W were respectively set to 30 and 2, and the orientation θ was set to 0, $\pi/4$, and $\pi/2$. The results of the experiment are shown in Fig. 7 to Fig. 9. The proposed method could generate ripple patterns on the entire image even in various photographic images. Additionally, the proposed method could control the orientation of ripple patterns in various photographic images.

4. Conclusion

This paper focused on ripple images by non-photorealistic rendering and proposed a method for generating ripple patterns with a texture different from the conventional method. The proposed method was executed by an iterative calculation using smoothing filter with the translated window. Experiments with various photographic images have shown that the proposed method can generate ripple patterns on the entire image and control the orientation of ripple patterns.

A subject for future study is to expand the proposed method for application to color photographic images, videos, and three-dimensional data.

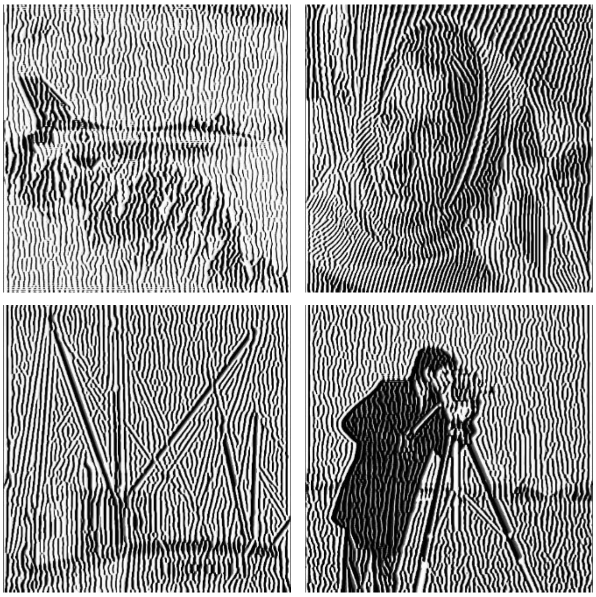


Fig.9. Various ripple images in the case of $\theta = \pi/2$

Acknowledgements

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