ICIC Express Letters
Volume **16**, Number **2**, February **2022**
ICIC International ©2022 ISSN 1881-803X
pp. 153–158

GENERATION OF FINGERPRINT-PATTERN IMAGES USING COSINE-WAVE-WEIGHT SMOOTHING FILTER

Toru Hiraoka
Department of Information Systems
University of Nagasaki
1-1-1, Manabino, Nagayo-chou, Nishisonogi-gun, Nagasaki-ken 851-2195, Japan
hiraoka@sun.ac.jp

Received July 2021; accepted September 2021

Abstract. *A non-photorealistic rendering method for generating fingerprint-pattern images from gray-scale photographic images has been proposed. However, the conventional method cannot generate fingerprint patterns in white areas in photographic images. Therefore, we propose a method that can generate fingerprint patterns even in the white areas. The proposed method is executed by an iterative calculation using an unprecedented new filter called a cosine-wave-weight filter. To verify the effectiveness of the proposed method, we conducted an experiment using some gray-scale photographic images to confirm that fingerprint patterns can be generated in the white areas. In addition, we also conducted an experiment to visually examine how fingerprint patterns generated by changing the values of the parameters in the proposed method change.*
Keywords: Non-photorealistic rendering, Fingerprint pattern, Cosine-wave-weight smoothing filter, Photographic image

1. **Introduction.** In recent years, in the field of computer graphics (CG) [1,2], a technology called non-photorealistic rendering (NPR) has been attracting attention [3-9]. General CG focuses on expressing virtual things on a computer closer to those in the real world. NPR, on the other hand, produces non-realistic images from photographic images, videos, and three-dimensional data that are copies of the real world. For example, NPR automatically converts photographic images into non-realistic images of artistic expressions such as oil painting, watercolors, pencil drawings, and sand paintings. In addition, NPR has also appeared that converts photographic images into non-realistic images of unprecedented artistic styles such as moire images [10], reaction-diffusion-pattern images [11,12], fingerprint-pattern images [13], and interference-streak images [14].

We focus on the NPR of fingerprint-pattern images. Fingerprint-pattern images are non-realistic images obtained by overlaying fingerprint patterns on gray-scale photographic images. The conventional method [13] is executed by an iterative calculation using an inverse filter [15] and a shifted smoothing filter. The conventional method cannot generate fingerprint patterns in white areas in photographic images as shown by the yellow circles in Figure 1. Therefore, if fingerprint patterns can be generated even in the white areas, the appearance of fingerprint-pattern images will be improved.

We propose a new method that can generate fingerprint patterns in the white areas. The proposed method is executed by an iterative calculation using an unprecedented new filter called a cosine-wave-weight filter. The cosine-wave-weight filter converts the pixel value by weighing the cosine wave according to the distance from the target pixel. In the white areas, the conventional method uses the shifted smoothing filter and the pixel value does not change, but the proposed method can generate areas where the pixel value changes using the cosine-wave-weight filter. Through an experiment using four

DOI: 10.24507/icicel.16.02.153

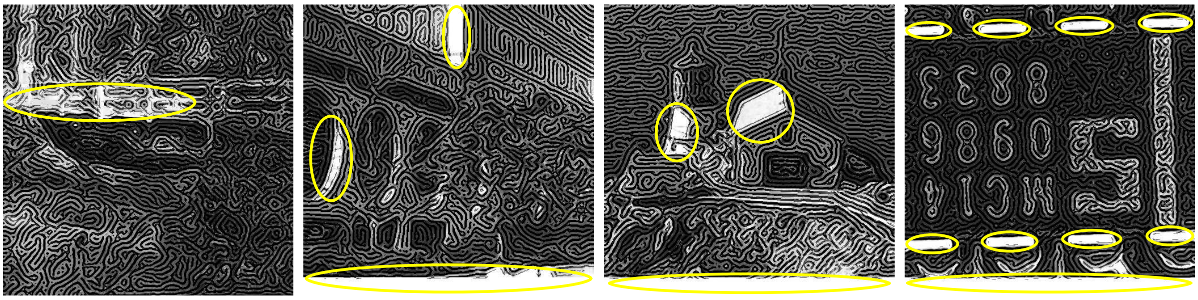


FIGURE 1. Conventional fingerprint-pattern images

photographic images, it was found that the proposed method can generate fingerprint patterns in the white areas that could not be generated by the conventional method. It was also found that fingerprint patterns generated by the proposed and conventional methods have slightly different shapes, but the proposed method can express fingerprint patterns more clearly than the conventional method. In addition, through an experiment that the values of the parameters in the proposed method were changed, it was found that the interval and texture of fingerprint patterns can be changed.

The rest of this paper is organized as follows. Section 2 describes the proposed method for generating fingerprint-pattern images. Section 3 shows experimental results, and reveals the effectiveness of the proposed method. Finally, Section 4 concludes this paper.

2. **Proposed Method.** The proposed method is largely executed in two steps. In the first step, fingerprint patterns are generated from photographic images by the iterative calculation using the cosine-wave-weight filter. In the second step, fingerprint-pattern images are created by synthesizing finger patterns generated in the first step and photographic images. A flow chart of the proposed method is shown in Figure 2.

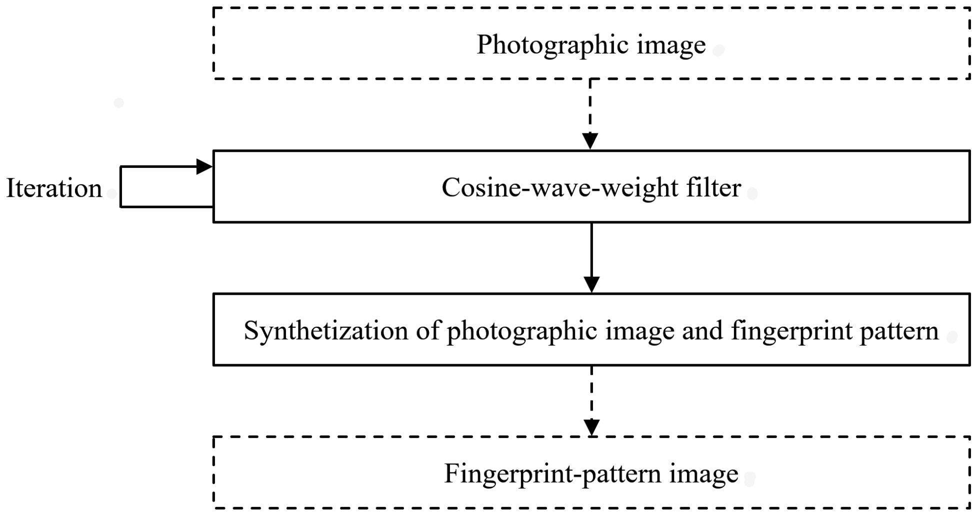


FIGURE 2. Flow chart of the proposed method

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 U gradation from 0 to $U - 1$.

Step 1: The pixel values $f_{i,j}^{(t-1)}$ are smoothed using pixel values within window size W, where t is the iteration number and $f_{i,j}^{(0)} = f_{i,j}$. The pixel values $f_{i,j}^{(t)}$ are converted using the cosine-wave-weight filter as follows.

$$f_{i,j}^{(t)} = f_{i,j}^{(t-1)} + a \frac{\sum_{k=-W}^{W} \sum_{l=-W}^{W} f_{i+k,j+l}^{(t-1)} \cos \frac{2\pi\sqrt{(i-k)^2+(j-l)^2}}{W}}{M} \tag{1}$$

Subject to processing target when $\sqrt{(i-k)^2+(j-l)^2} \leq W$

where k and l are the positions in the window, a is a positive constant, and M is the number of pixels within radius W from the coordinates (i, j). If $f_{i,j}^{(t)}$ is smaller than 0, then $f_{i,j}^{(t)}$ must be set to 0, and if $f_{i,j}^{(t)}$ is greater than $U-1$, then $f_{i,j}^{(t)}$ must be set to $U-1$. In Equation (1), it is possible to bring the white areas (pixel value $U-1$) closer to black (pixel value 0) by taking negative values of cosine. Step 1 is repeated T times.

Step 2: The pixel values $o_{i,j}$ after overlaying the fingerprint patterns on the photographic image are calculated as follows.

$$o_{i,j} = \begin{cases} f_{i,j}^{(T)} & \left(f_{i,j}^{(T)} < U/2\right) \\ f_{i,j} & \left(f_{i,j}^{(T)} \geq U/2\right) \end{cases} \tag{2}$$

If $f_{i,j}^{(T)}$ is smaller than $U/2$, then $o_{i,j}$ is equal to $f_{i,j}^{(T)}$, and if $f_{i,j}^{(T)}$ is greater than or equal to $U/2$, then $o_{i,j}$ is equal to $f_{i,j}$. An image composed of pixel values $o_{i,j}$ is a fingerprint pattern image.

3. **Experiments.** We conducted two experiments. In the first experiment, we visually confirmed fingerprint patterns by changing the values of the parameters in the proposed method using Woman image shown in Figure 3. In the second experiment, we visually confirmed that fingerprint patterns can be generated in the white areas using four photographic images shown in Figure 4. All photographic images used in the experiments were $512 * 512$ pixels and 256 gradation. In the following experiments, the parameters T, W, and a were based on 40, 10, and 10, respectively, because fingerprint patterns were easy to see in fingerprint-pattern images of $512 * 512$ pixels and 256 gradation.

Figure 3. Woman image

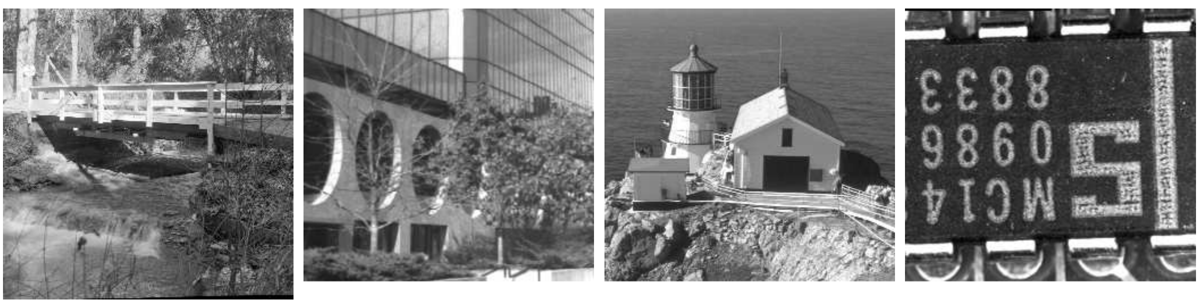
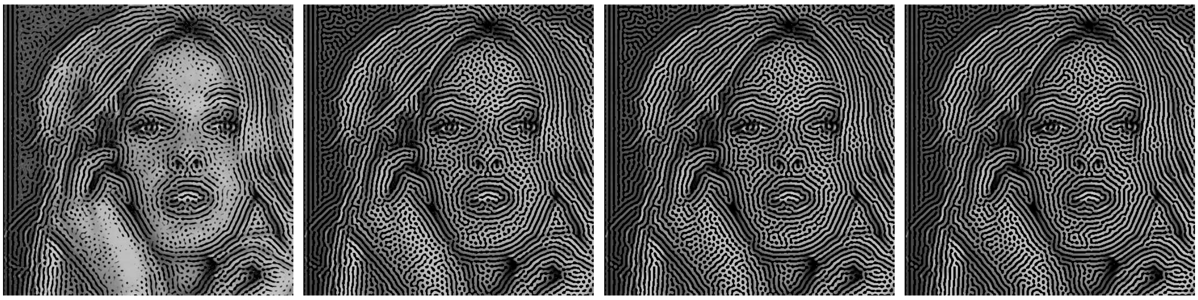


Figure 4. Photographic images

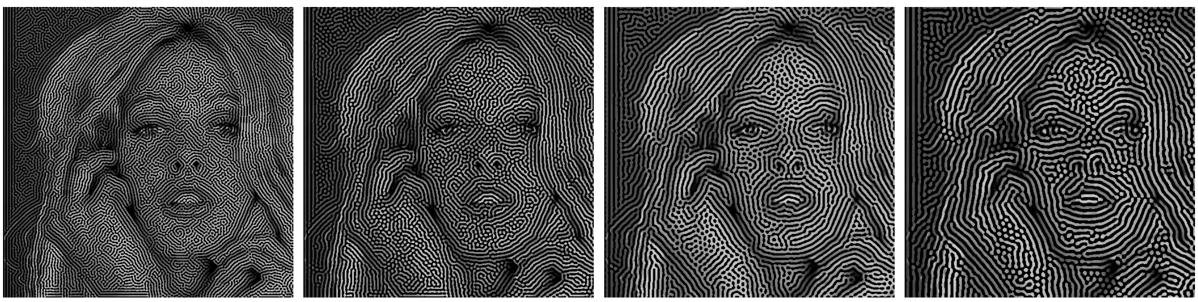
3.1. **Experiment with changing parameters.** Fingerprint-pattern images generated by changing the iteration number T were confirmed visually. The iteration number T was set to 5, 10, 20, and 40. The parameters W and a were set to 10 and 10, respectively. The results of the experiment are shown in Figure 5. As the value of T was larger, fingerprint patterns became clearer and were expressed finely. Further, the smaller the change in the pixel value, the slower the generation of fingerprint patterns. Thus, for photographic images that the change in the pixel value is small, it is necessary to increase the value of T in order to clearly generate fingerprint patterns.



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

FIGURE 5. Fingerprint-pattern images in the case of the iteration number $T = 5$, 10, 20, and 40

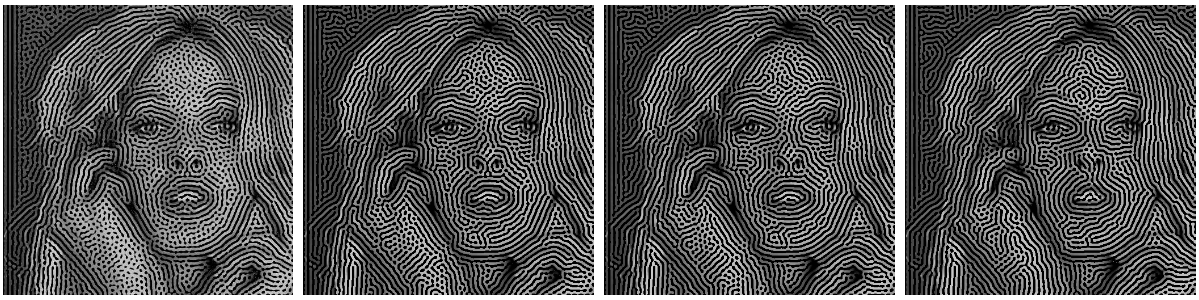
Fingerprint-pattern images generated by changing the window size W were confirmed visually. The window size W was set to 6, 8, 10, and 12. The parameters T and a were set to 40 and 10, respectively. The results of the experiment are shown in Figure 6. As the value of W was larger, the interval of fingerprint patterns became wider. Furthermore, the size of fingerprint patterns increased in proportion to the value of W.



(a) $W = 6$ (b) $W = 8$ (c) $W = 10$ (d) $W = 12$

FIGURE 6. Fingerprint-pattern images in the case of the window size $W =$ 6, 8, 10, and 12

Fingerprint-pattern images generated by varying the parameter a were confirmed visually. The parameter a was set to 1, 10, 20, and 40. The parameters T and W were set to 40 and 10, respectively. The results of the experiment are shown in Figure 7. As the value of a was larger, the number of short fingerprint patterns was reduced. Furthermore, short fingerprint patterns were more generated in the areas where the change in the pixel value was smaller.



(a) $a = 1$ (b) $a = 10$ (c) $a = 20$ (d) $a = 40$

FIGURE 7. Fingerprint-pattern images in the case of the parameter $a = 1$, 10, 20, and 40

3.2. **Experiment using four photographic images.** The proposed method was applied to four photographic images shown in Figure 4. In order to generate fingerprint patterns similar to the interval of fingerprint patterns generated by the conventional method in Figure 1, the parameters T, W, and a were set to 40, 10, and 10, respectively. The results of the experiment are shown in Figure 8. Looking at the yellow circles in Figure 8, the proposed method could generate fingerprint patterns even in the white areas where the conventional method could not generate fingerprint patterns. From fingerprint-pattern images on the left in Figure 4, the number of the white (pixel vale 255) pixels was 385, 19768, 16972, and 22297, respectively. From fingerprint-pattern images on the left in Figure 8, the number of the white pixels was 253, 10865, 9539, and 11860, respectively. Since the number of white pixels in Figure 8 was smaller than that in Figure 4, it is considered that the proposed method can generate more fingerprint patterns in the white areas than the conventional method. In addition, fingerprint-pattern generated by the proposed and conventional methods had slightly different shapes, but the proposed method could express fingerprint patterns more clearly than the conventional method.

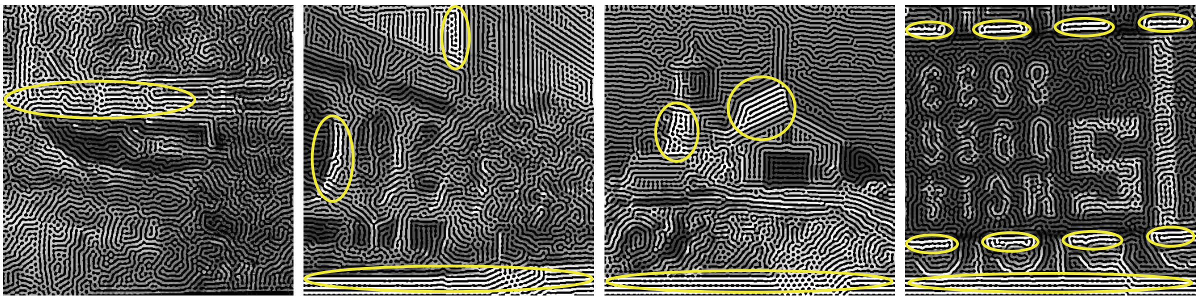


FIGURE 8. Fingerprint-pattern images

4. **Conclusions.** We proposed a new NPR method for generating fingerprint-pattern images from gray-scale photographic images using a cosine-wave-weight smoothing filter. Through an experiment using four photographic images, it was found that the proposed method can generate fingerprint patterns in the white areas where the conventional method could not generate fingerprint patterns. It was also found that fingerprint patterns generated by the proposed and conventional methods have slightly different shapes, but the proposed method can express fingerprint patterns more clearly than the conventional method. In addition, through an experiment that the values of the parameters in the proposed method were changed, it was found that the interval of fingerprint patterns and the number of short fingerprint patterns can be changed.

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

REFERENCES

[1] H. Shen, Z. Zhang and Z. Shang, Fast global rendering in virtual reality via linear integral operators, *International Journal of Innovative Computing, Information and Control*, vol.15, no.1, pp.67-77, 2019.

[2] L. Xue, X. Yi, Y.-C. Lin and J. W. Drukker, An approach of the product form design based on GRA-fuzzy logic model: A case study of train seats, *International Journal of Innovative Computing, Information and Control*, vol.15, no.1, pp.261-274, 2019.

[3] P. Haeberli, Paint by numbers: Abstract image representations, *ACM SIGGRAPH Computer Graphics*, vol.24, no.4, pp.207-214, 1990.

[4] J. Lansdown and S. Schofield, Expressive rendering: A review of nonphotorealistic techniques, *IEEE Computer Graphics and Applications*, vol.15, no.3, pp.29-37, 1995.

[5] D.-L. Way, M.-K. Yang, Z.-C. Shih and R.-R. Lee, A colored pencil non-photorealistic rendering for 2D images, *International Journal of Innovative Computing, Information and Control*, vol.10, no.1, pp.233-241, 2014.

[6] A. Werth, Turing patterns in Photoshop, *Proc. of Bridges 2015: Mathematics, Music, Art, Architecture, Culture*, pp.459-462, 2015.

[7] D. Martin, G. Arroyo, A. Rodriguez and T. Isenberg, A survey of digital stippling, *Computers & Graphics*, vol.67, pp.24-44, 2017.

[8] W. Qian, D. Xu, J. Cao, Z. Guan and Y. Pu, Aesthetic art simulation for embroidery style, *Multimedia Tools and Applications*, vol.78, no.1, pp.995-1016, 2019.

[9] I. Ilinkin, Designing a course on non-photorealistic rendering, *Eurographics*, pp.9-16, 2020.

[10] T. Hiraoka and K. Urahama, Generation of moire-picture-like color images by bilateral filter, *IEICE Trans. Information and Systems*, vol.E96-D, no.8, pp.1862-1866, 2013.

[11] M. T. Chi, W. C. Liu and S. H. Hsu, Image stylization using anisotropic reaction diffusion, *The Visual Computer*, vol.32, no.12, pp.1549-1561, 2016.

[12] C. W. Jho and W. H. Lee, Real-time tonal depiction method by reaction-diffusion mask, *Journal of Real-Time Image Processing*, vol.13, no.3, pp.591-598, 2017.

[13] T. Hiraoka and Y. Tsurunari, Generation of fingerprint-pattern-like images using shifted smoothing filter, *ICIC Express Letters*, vol.13, no.12, pp.1133-1138, 2019.

[14] T. Hiraoka, Generation of interference-streak images by bilateral filter with operation between RGB, *ICIC Express Letters*, vol.15, no.4, pp.343-348, 2021.

[15] Z. Yu and K. Urahama, Iterative method for inverse nonlinear image processing, *IEICE Trans. Fundamentals*, vol.E97-A, no.2, pp.719-721, 2014.