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GENERATION OF FINGERPRINT-PATTERN-LIKE IMAGES USING SHIFTED SMOOTHING FILTER

Toru Hiraoka[1] and Yoshihisa Tsurunari[2]

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

[2]Institute for Innovative Collaboration Promotion
Oita University
700, Dannoharu, Oita-shi, Oita-ken 870-1192, Japan
y-tsurunari@oita-u.ac.jp

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Abstract. *We propose a non-photorealistic rendering (NPR) method for generating fingerprint-pattern-like images (FPL images) from gray-scale photographic images. FPL images are non-photorealistic images obtained by overlaying fingerprint patterns on photographic images. Our method is performed in two steps. In the first step, photographic images are converted by processing using shifted smoothing filter. Fingerprint patterns are generated by repeating this process. In the second step, fingerprint patterns are overlaid on photographic images. Our method is simple and easy to implement. To validate the effectiveness of our method, we conducted experiments on Lenna image and other photographic images. As a result of the experiments, we show impressive FPL images.*
Keywords: Non-photorealistic rendering, Fingerprint pattern, Shifted smoothing filter, Automatic generation, Repetitive processing, Photographic image

1. **Introduction.** One of the techniques using image processing [1, 2, 3] is NPR. NPR is a theme that has attracted considerable attention recently in the computer graphics community [4, 5, 6, 7, 8]. Many NPRs are performed by programs that generate new output images within a specified artistic style from images or three-dimensional data. In the field of such NPR, many studies have been undertaken to develop unprecedented art expressions such as maze-like images [9, 10], moire-like images [11], reaction-diffusion-pattern-like images [12, 13], and cell-like images [14] imitating patterns in nature and human society. Also, studies have been conducted to generate op-art-like images [15, 16] that bring various visual effects. Maze-like images [9] are generated using minimum spanning trees, moire-like images [11] using bilateral filter, reaction-diffusion-pattern-like images [12] using anisotropic reaction diffusion, cell-like images [14] using inverse iris filter, and op-art-like images [15] using a global optimization technique and an algorithm based on a physical simulation of heat flow. At present, many applications for converting photographic images to non-photorealistic images by NPR are embedded in social networking service (SNS) and the like, and many users upload non-photorealistic images to SNS and website in order to simulate user's playfulness.

In this paper, we focus on fingerprint patterns as an unprecedented art expression, and then propose an NPR method for generating FPL images from gray-scale photographic images. FPL images are non-photorealistic images obtained by overlaying fingerprint patterns on photographic images. By developing the NPR method for generating FPL images, it will be possible to provide more diverse NPR on SNS and website. A method

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for generating patterns like a fingerprint from photographic images has also been proposed [17]. Although the conventional method uses flow-guided anisotropic filter, our method uses shifted smoothing filter which can be implemented more easily. Like the conventional method, our method is that fingerprint patterns can be automatically generated according to the changes in luminance values of photographic images. In order to visually verify the effectiveness of our method, we examined the way that fingerprint patterns form in our method when parameters were varied through experiments with Lenna image. In addition, we applied our method to various photographic images. As a result of the experiments, we show that fingerprint patterns can be automatically generated on the whole image.

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

2. **Our Method.** Our method generates FPL images from gray-scale photographic images. Our method is largely executed in two processes. The first process converts photographic images using shifted smoothing filter. Fingerprint patterns are generated by repeating this process. The second process overlays fingerprint patterns on photographic images. A flow chart of our method is shown in Figure 1.

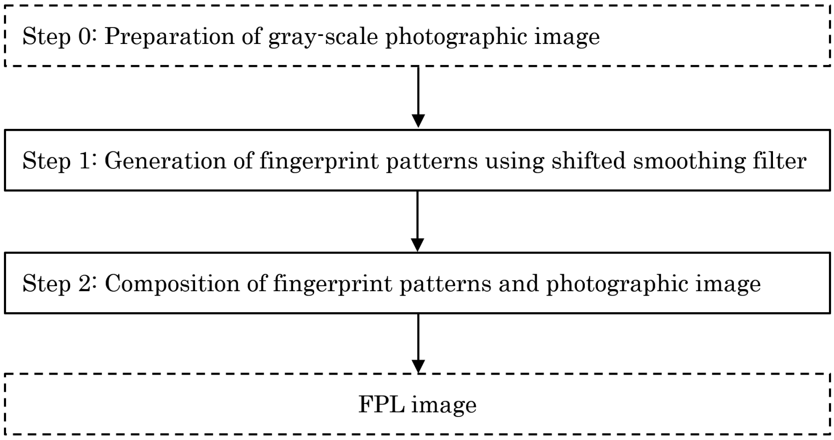

Figure 1. Flow chart of our method

Details of the steps in Figure 1 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 $f_{i,j}^{(0)} = f_{i,j}$. Let the smoothed pixel values be $s_{i,j}^{(t)}$ as follows.

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

where k and l are the positions in the window. Let the pixel values smoothed similarly to Equation (1) for the pixel (k, l) in the window of size W centered on the pixel (i, j) be $s_{k,l}^{(t)}$. The absolute values of the difference between the pixel values $s_{i,j}^{(t)}$ and $s_{k,l}^{(t)}$ within window size W are calculated. Let the absolute values of the difference be $d_{i,j,k,l}^{(t)}$ as follows.

$$d_{i,j,k,l}^{(t)} = \left| s_{i,j}^{(t)} - s_{k,l}^{(t)} \right| \tag{2}$$

Let the pixel values $s_{k,l}^{(t)}$ of the coordinate (k, l) where $d_{i,j,k,l}^{(t)}$ is the maximum value within window size W be $g_{i,j}^{(t)}$. The filter that converts to the pixel values $g_{i,j}^{(t)}$ is called shifted smoothing filter. The pixel values $f_{i,j}^{(t)}$ are converted using the pixel values $g_{i,j}^{(t)}$ as follows.

$$f_{i,j}^{(t)} = g_{i,j}^{(t)} - f_{i,j}^{(t-1)} + f_{i,j} \tag{3}$$

where in case $f_{i,j}^{(t)}$ is smaller than 0, $f_{i,j}^{(t)}$ must be set to 0. In case $f_{i,j}^{(t)}$ is greater than $U-1$, $f_{i,j}^{(t)}$ must be set to $U-1$. The above process is repeated T times.

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

$$o_{i,j} = \begin{cases} f_{i,j}^{(T)} & \left(f_{i,j}^{(T)} < U/2\right) \\ f_{i,j} & \left(f_{i,j}^{(T)} \geq U/2\right) \end{cases} \tag{4}$$

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 an FPL image.

3. **Experiments.** We conducted two experiments. In the first experiment, we visually confirmed fingerprint patterns by varying the values of the parameters in our method using Lenna image shown in Figure 2. In the second experiment, we visually confirmed FPL images generated from other photographic images. All photographic images used in the experiments were 512 × 512 pixels and 256 gradation.

Figure 2. Lenna image

3.1. **Experiment with varying parameters.** FPL images by varying the iteration number T were confirmed visually. The iteration number T was set to 5, 15, and 30. The window size W was set to 1. The results of experiment are shown in Figure 3. As the value of T was larger, fingerprint patterns became clearer and were expressed finely.

FPL images by varying the window size W were confirmed visually. The window size W was set to 1, 2, and 3. The iteration number T was set to 30. The results of experiment are shown in Figure 4. As the value of W was larger, the width of fingerprint patterns became wider.

3.2. **Experiment using various photographic images.** Our method was applied to six gray-scale photographic images shown in Figure 5. Since fingerprint patterns were visually recognized well in the previous experiments, the parameters T and W were set to 30 and 1, respectively. The results of the experiment are shown in Figure 6. In all FPL images, fingerprint patterns could be automatically generated according to the changes in luminance values of photographic images. However, fingerprint patterns were less likely

(a) $T = 5$ (b) $T = 15$ (c) $T = 30$

FIGURE 3. FPL images in the case of the iteration number $T = 5$, 15, and 30

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

FIGURE 4. FPL images in the case of the window size $W = 1$, 2, and 3

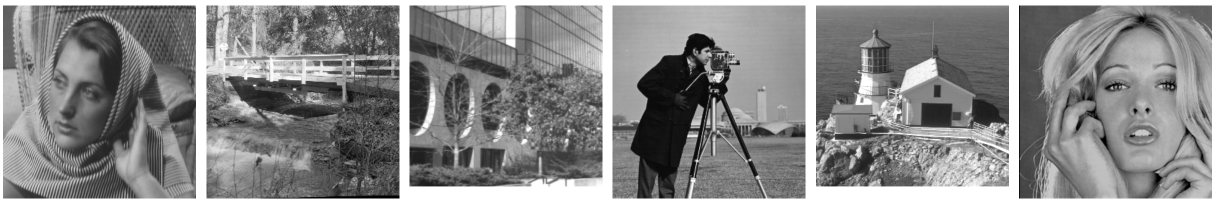

FIGURE 5. Photographic images

to occur in white and bright areas. Comparing our method with the conventional method [17], the conventional method could generate patterns near the edges of photographic images and made it difficult to generate patterns in the other areas, but our method could generate many patterns other than near the edges than the conventional method.

4. **Conclusions.**

We proposed a new NPR method for generating FPL images from gray-scale photographic images using shifted smoothing filter. Our method had features that the processing is simple and fingerprint patterns can be automatically generated according to the changes in luminance values of photographic images. In the experiments using Lenna image and other photographic images, we clarified that our method can practically realize these features. However, we found out that fingerprint patterns are less likely to occur in white and bright areas.

FIGURE 6. FPL images

A subject for future study is to be able to generate fingerprint patterns in white and bright areas. Another task is to expand the proposed method for application to color photographic images.

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