ICIC Express Letters
Volume **13**, Number **11**, November **2019**
 ISSN 1881-803X
pp. 1031–1037

A METHOD FOR EMPHASIZING AND ALIGNING PATTERNS IN CELL-LIKE IMAGES

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Received May 2019; accepted July 2019

Abstract. *A non-photorealistic rendering method has been proposed for generating cell-like images by an iterative process using inverse iris filter from photographic images. Cell-like images are overlaid with cell patterns in photographic images. Since cell patterns are automatically generated according to the change in density and the edges of photographic images, the arrangement of cell patterns is irregular and cell patterns are hard to occur in regions where the change in density is small. We in this paper propose a method to emphasize and align cell patterns. Our method is implemented by synthesizing sine and cosine waves into photographic images. We visually verified the effectiveness of our method through experiments using various photographic images. As a result of the experiments, we revealed that cell patterns are emphasized and aligned to improve the appearance of cell-like images.*
Keywords: Non-photorealistic rendering, Cell, Emphasis, Alignment, Inverse iris filter

1. **Introduction.** Many non-photorealistic rendering methods for converting photographic images [1], videos and three-dimensional data into artistic images have been proposed [2, 3, 4, 5, 6, 7, 8]. In recent years, many non-photorealistic rendering methods have been proposed that imitate patterns of the natural world [9, 10, 11]. Oil-film-like images [9] were generated using bilateral infra-envelope filter, reaction-diffusion images [10] were generated by a processing based on anisotropic reaction diffusion, and bubble images [11] were generated using additive and multiplication averages in different window sizes.

One of these non-photorealistic rendering methods that imitate the patterns of the natural world is a method to generate cell-like images from photographic images [12]. Also, the conventional method is extended to a method that generates cell-like animations from videos [13]. The conventional method is executed by an iterative process using inverse iris filter. Cell-like images are overlaid with cell patterns in photographic images. Cell patterns are automatically generated according to the change in density and the edges of photographic images. Then, the conventional method has the features that black cell patterns are arranged along the edges of photographic images and the arrangement of black cell patterns is irregular in areas other than the edges. In addition, the conventional method has the disadvantage that cell patterns are less likely to occur in areas where the change in density is small. Therefore, it is considered that the appearance of cell-like images is improved by aligning cell patterns and generating cell patterns also in the areas where the change in density is small.

In this paper, we propose a method for emphasizing and aligning cell patterns in cell-like images. Our method is implemented by synthesizing sine and cosine waves into photographic images. To validate the effectiveness of our method, an experiment using Lenna image by changing the parameters of sine and cosine waves was conducted. In

DOI: 10.24507/icicel.13.11.1031

addition, an experiment to apply our method to various photographic images was also conducted. The experimental results show that our method can generate cell patterns in alignment and in the areas where the change in density is small.

This paper is organized as follows: the second section describes our method for emphasizing and aligning cell patterns, the third section shows experimental results and reveals the effectiveness of our method, and the conclusion of this paper is given in the fourth section.

2. **Our Method.** Our method generates cell-like images that cell patterns are emphasized and aligned from photographic images. Our method is implemented in two major steps. The first step is to synthesize sine and cosine waves into photographic images. The second step is to generate cell-like images by the iterative process using inverse iris filter. Inverse iris filter is a combination of inverse filter [14, 15] and iris filter [16, 17]. Inverse filter restores images transformed by a process to original images, and iris filter calculates the concentration of gradient vectors. The flow chart of our method is shown in Figure 1.

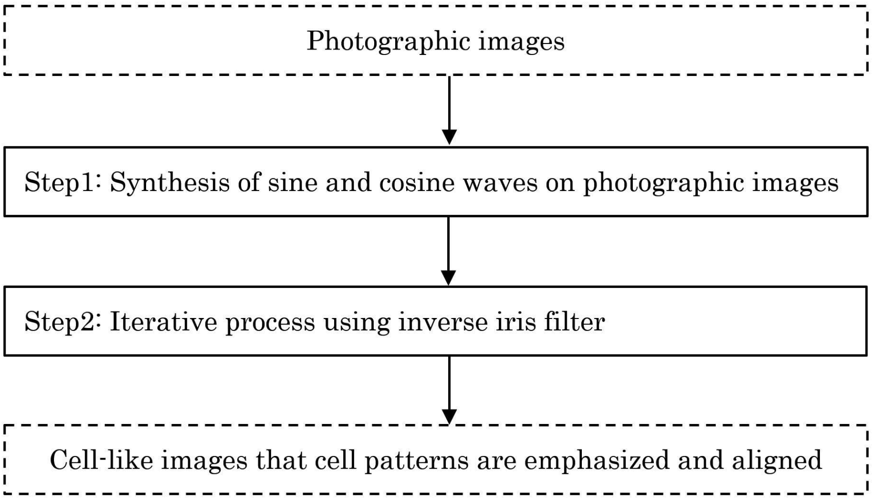

FIGURE 1. Flow chart of our method

Details of the procedure in Figure 1 are explained below.

Step 0: Let input pixel values of RGB on coordinates (i, j) in color photographic image be $o_{R,i,j}$, $o_{G,i,j}$ and $o_{B,i,j}$ ($i = 1, 2, \ldots, I$; $j = 1, 2, \ldots, J$). The pixel values $o_{R,i,j}$, $o_{G,i,j}$ and $o_{B,i,j}$ have value of 256 gradation from 0 to 255.

Step 1: Let pixel values of the image obtained by synthesizing sine and cosine waves into photographic image be $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$. In compliance with image data widely used in the world, the pixel values $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ are calculated as follows.

$$f_{R,i,j} = o_{R,i,j} + A \sin\left(\frac{\pi i}{D}\right) \cos\left(\frac{\pi j}{D}\right) \tag{1}$$

$$f_{G,i,j} = o_{G,i,j} + A \sin\left(\frac{\pi i}{D}\right) \cos\left(\frac{\pi j}{D}\right) \tag{2}$$

$$f_{B,i,j} = o_{B,i,j} + A \sin\left(\frac{\pi i}{D}\right) \cos\left(\frac{\pi j}{D}\right) \tag{3}$$

where A and D are parameters for adjusting the wave amplitude and the wave period, respectively. If $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ are less than 0, then these values must be set to 0, respectively. If $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ are greater than 255, then these values must be set to 255, respectively. Gray-scale pixel values $f_{i,j}$ are calculated as follows.

$$f_{i,j} = \frac{f_{R,i,j} + f_{G,i,j} + f_{B,i,j}}{3} \tag{4}$$

Step 2: Let output pixel values after processing with iris filter on $f_{i,j}$ be $IF(f_{i,j})$. Iris filter is executed with the S peripheral pixels (k, l) in the radius r pixels from the target pixel (i, j). Angles $\theta_{i,j,k,l}$ between a vector $(i-k, j-l)$ from the peripheral pixels (k, l) to the target pixel (i, j) and a vector $((f_{k+2,l+2} + f_{k+2,l+1} + f_{k+2,l} + f_{k+2,l-1} + f_{k+2,l-2}) - (f_{k-2,l+2} + f_{k-2,l+1} + f_{k-2,l} + f_{k-2,l-1} + f_{k-2,l-2}), (f_{k+2,l+2} + f_{k+1,l+2} + f_{k,l+2} + f_{k-1,l+2} + f_{k-2,l+2}) - (f_{k+2,l-2} + f_{k+1,l-2} + f_{k,l-2} + f_{k-1,l-2} + f_{k-2,l-2}))$ are computed. Let convergence indices of the target pixel (i, j) be $c_{i,j}$. The convergence indices $c_{i,j}$ are calculated as follows.

$$c_{i,j} = \frac{1}{S}\left|\sum_{k=i-r}^{i+r}\sum_{l=j-r}^{j+r}\cos\theta_{i,j,k,l}\right| \tag{5}$$

Let minimum and maximum values of $c_{i,j}$ in all pixels be $c_{\min}$ and $c_{\max}$, respectively. The convergence indices $c_{i,j}$ are converted to $C_{i,j}$ as follows.

$$C_{i,j} = 255\left(\frac{c_{i,j} - c_{\min}}{c_{\max} - c_{\min}}\right) \tag{6}$$

The values $IF(f_{i,j})$ and $C_{i,j}$ are the same value.

Pixel values $f^{(t)}_{R,i,j}$, $f^{(t)}_{G,i,j}$ and $f^{(t)}_{B,i,j}$ are computed by using inverse iris filter as follows.

$$f^{(t)}_{R,i,j} = a\left(f^{(t-1)}_{i,j} - IF\left(f^{(t-1)}_{i,j}\right)\right) + f_{R,i,j} \tag{7}$$

$$f^{(t)}_{G,i,j} = a\left(f^{(t-1)}_{i,j} - IF\left(f^{(t-1)}_{i,j}\right)\right) + f_{G,i,j} \tag{8}$$

$$f^{(t)}_{B,i,j} = a\left(f^{(t-1)}_{i,j} - IF\left(f^{(t-1)}_{i,j}\right)\right) + f_{B,i,j} \tag{9}$$

$$f^{(t-1)}_{i,j} = \frac{f^{(t-1)}_{R,i,j} + f^{(t-1)}_{G,i,j} + f^{(t-1)}_{B,i,j}}{3} \tag{10}$$

where a is positive constant, t is the number of iterations, $f^{(0)}_{R,i,j} = f_{R,i,j}$, $f^{(0)}_{G,i,j} = f_{G,i,j}$ and $f^{(0)}_{B,i,j} = f_{B,i,j}$. If $f^{(t)}_{R,i,j}$, $f^{(t)}_{G,i,j}$ and $f^{(t)}_{B,i,j}$ are less than 0, then these values must be set to 0, respectively. If $f^{(t)}_{R,i,j}$, $f^{(t)}_{G,i,j}$ and $f^{(t)}_{B,i,j}$ are greater than 255, then these values must be set to 255, respectively. A cell-like image that cell patterns are emphasized and aligned is obtained after processing of inverse iris filter of T times iteration.

3. **Experiments.** First, we visually verified the effectiveness of our method through the experiment by changing the parameters of sine and cosine waves using Lenna image shown in Figure 2. Next, we applied our method to various photographic images. All images were $512 * 512$ pixels and 256 gradation. Refer to [12] in all experiments, we set T, r and a to 20, 3 and 5, respectively. By setting these parameters in this manner, cell patterns can be clearly represented in cell-like images of $512 * 512$ pixels.

For reference, a cell-like image generated by the conventional method from Lenna image is shown in Figure 3. Observing Figure 3, cell patterns were less likely to occur in the white area of the lower right where the change in density is small. And, cell patterns were arranged along the edges of Lenna image and the arrangement of black cell patterns was irregular in areas other than the edges.

Figure 2. Lenna image

Figure 3. Cell-like image generated by the conventional method

(a) $A = 10$ (b) $A = 30$ (c) $A = 50$

Figure 4. Cell-like images generated by our method in the case of changing the value of the wave amplitude A

3.1. **Experiment with different parameter values.** We visually confirmed cell-like images generated by changing the values of the wave amplitude A using Lenna image. The value of A was set to 10, 30 and 50. The value of D was set to 10. The results of the experiment are shown in Figure 4. Observing Figure 4, as the value of A became larger, cell patterns became clear and the black part of cell patterns became larger. In all cases, cell patterns could be generated also in the white area of the lower right where the change in density is small. And, our method could emphasize cell patterns more than the conventional method.

We visually confirmed cell-like images generated by changing the values of the wave period D using Lenna image. The value of D was set to 5, 10 and 15. The value of A was set to 30. The results of the experiment are shown in Figure 5. Observing Figure

(a) $D = 5$ (b) $D = 10$ (c) $D = 15$

FIGURE 5. Cell-like images generated by our method in the case of changing the value of the wave period D

FIGURE 6. Various photographic images

5, as the value of D became smaller, the spacing between cell patterns became narrower, the black part of cell patterns became smaller, and the black part of cell patterns became more circular. In all cases, cell patterns could be generated also in the white area of the lower right where the change in density is small. And, our method could emphasize cell patterns more than the conventional method.

3.2. **Experiment using various photographic images.** We applied our method to six photographic images shown in Figure 6. Since cell patterns were visually recognized well in the previous experiments, the values of A and D were set to 30 and 10, respectively. The results of the experiment are shown in Figure 7. Observing Figure 7, in all cases, cell patterns were generated in alignment on the whole image, and cell patterns were arranged along the edges of photographic images.

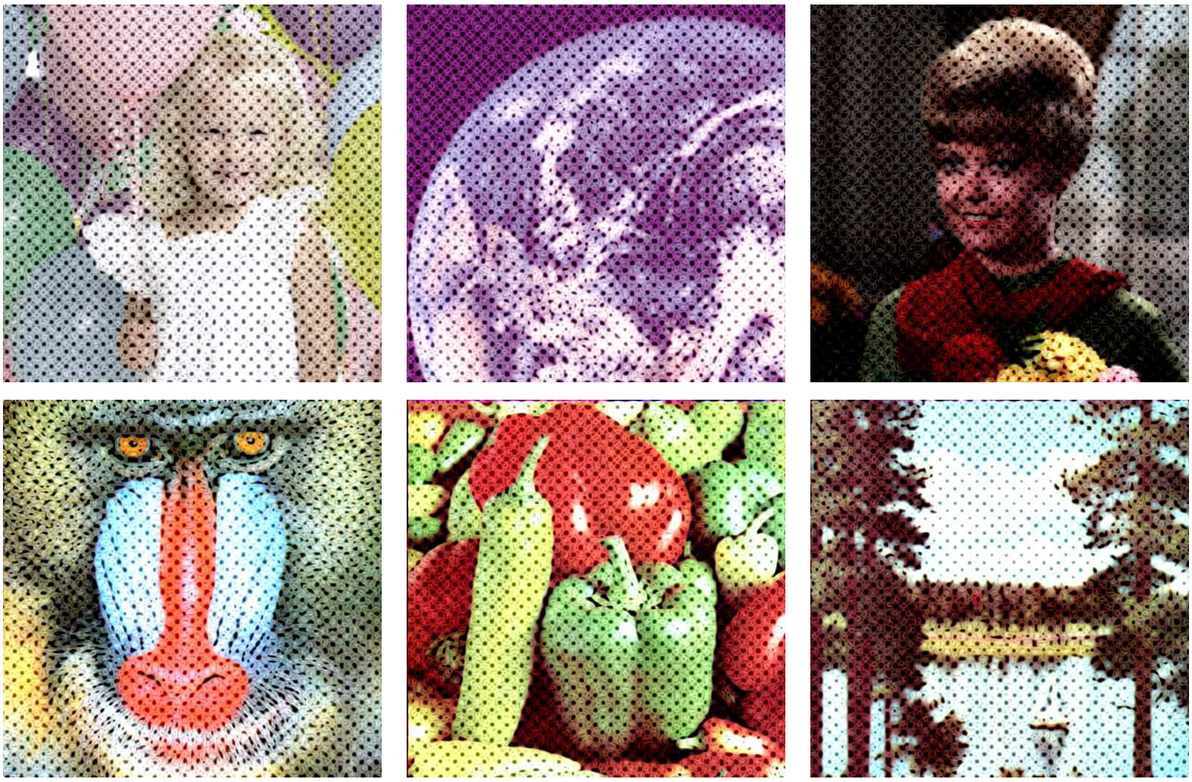

FIGURE 7. Cell-like images generated by our method

4. **Conclusions.** We proposed a method for emphasizing and aligning cell patterns in cell-like images. Our method was implemented by synthesizing sine and cosine waves into photographic images. We demonstrated the effectiveness of our method through experiments using various photographic images. The experimental results showed that our method can generate cell patterns in alignment and in the areas where the change in density is small, and can emphasize cell patterns more than the conventional method.

In future work, we will try to conduct experiments applying waves of various shapes by sine and cosine waves. And, we will try to apply our method to videos and three-dimensional data.

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