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GENERATING CELL-LIKE COLOR IMAGES BY INVERSE IRIS FILTER

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Abstract. *In recent years, non-photorealistic rendering has gathered interest as a technique of computer graphics. As a field of non-photorealistic rendering, researches have been studied actively to generate patterns such as labyrinth and stripe. We propose a non-photorealistic rendering method for generating cell-like color images that are overlaid with cell patterns in photographic color images. Our method generates cell-like color images by an iterative process using an inverse iris filter. To validate the effectiveness of our method, we conduct experiments on a color image of Lena by changing the parameters of the inverse iris filter visually. As an additional experiment, we apply our method to several photographic color images.*
Keywords: Non-photorealistic rendering, Cell, Inverse filter, Iris filter

1. **Introduction.** Non-photorealistic rendering is a technique of computer graphics that converts an original photographic image or 3-dimensional model into an art form such as pointillism [1, 2, 3], labyrinthine image [4, 5, 6, 7], stripes image [8, 9] and cartoon [10, 11]. Non-photorealistic rendering is used in a wide range of applications, for example, applications embedded in a personal computer and a portable terminal. Non-photorealistic rendering has recently become an area of active research. To develop a variety of non-photorealistic rendering methods, it is expected to be able to contribute to the development of the technology and the paradigm in the non-photorealistic rendering field.

In this letter, we propose a non-photorealistic rendering method for generating cell-like color images that are overlaid with cell patterns in photographic color images. Cell-like color images are composed of cell patterns that are formed from a cell membrane and a cell nucleus as shown in Figure 1, and are characterized to easily recognize a contour region because black cell patterns are arranged along the contour of photo color images. So far as we know, non-photorealistic rendering methods for generating cell-like color images have not been presented until now.

Our method generates cell-like color images by an iterative process using an inverse iris filter. The inverse iris filter is one of inverse filters [12, 13]. The inverse filter restores an image converted by some image processing procedures to an original image. The inverse iris filter is calculated by using a procedure that restores an image converted by an iris

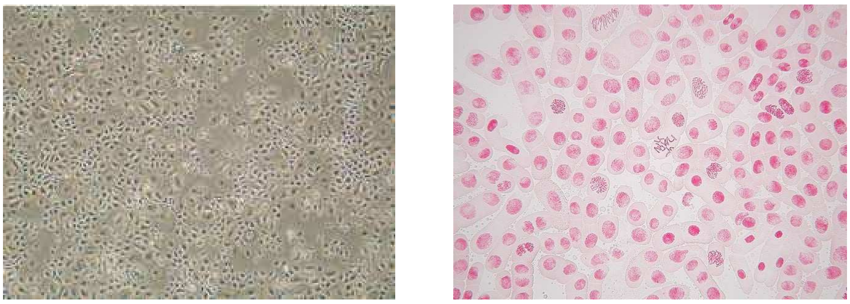

FIGURE 1. Example of cells

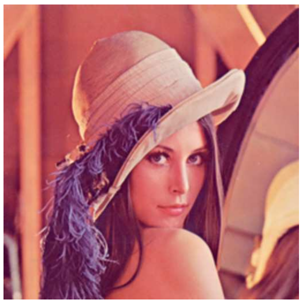

FIGURE 2. Color image of Lena

filter [14, 15] to an original image. To validate the effectiveness of our method, we conduct experiments on a color image of Lena shown in Figure 2 by changing the parameters of the inverse iris filter visually. As an additional experiment, we apply our method to several photographic color images and confirm the visual effects of cell-like color images.

2. **Our Method.** Our method generates cell-like color images by an iterative process using the inverse iris filter. The inverse iris filter is calculated by using a procedure that restores an image converted by an iris filter to an original image. As a further feature of our method, processing of iris filter is used for the gray-scale image of the original image in order to reduce the deviation of cell patterns in cell-like color images. The procedure of our method is as follows.

Let input pixel values of RGB on color image coordinates (i, j) be $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ $(i = 1, 2, \ldots, I;\ j = 1, 2, \ldots, J)$. The pixel values $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ have value of 256 gradation from 0 to 255. The gray scale pixel value $f_{i,j}$ is calculated by the following equation.

$$f_{i,j} = \frac{f_{R,i,j} + f_{G,i,j} + f_{B,i,j}}{3} \tag{1}$$

Let output pixel value after processing with the iris filter on $f_{i,j}$ be $IF(f_{i,j})$. The iris filter is executed with the peripheral pixels (k, l) in the radius r pixels from the target pixel (i, j). Compute the angle $\theta_{i,j,k,l}$ between a vector $(i - k, j - l)$ from the peripheral pixels (k, l) to the target pixel (i, j) and a vector $((f_{k+2,l+2} + f_{k+2,l+1} + f_{k+2,l} + f_{k+2,l-1} + f_{k+2,l-2}) - (f_{k-2,l+2} + f_{k-2,l+1} + f_{k-2,l} + f_{k-2,l-1} + f_{k-2,l-2}), (f_{k+2,l+2} + f_{k+1,l+2} + f_{k,l+2} + f_{k-1,l+2} + f_{k-2,l+2}) - (f_{k+2,l-2} + f_{k+1,l-2} + f_{k,l-2} + f_{k-1,l-2} + f_{k-2,l-2}))$. Let the convergence index of the target pixel (i, j) be $c_{i,j}$. The convergence index $c_{i,j}$ is calculated by the following equation.

$$c_{i,j} = \frac{1}{S} \left| \sum_{k=i-r}^{i+r} \sum_{l=j-r}^{j+r} \cos \theta_{i,j,k,l} \right| \tag{2}$$

Let the minimum and maximum values of $c_{i,j}$ in all pixels be $c_{\min}$ and $c_{\max}$, respectively. Convert $c_{i,j}$ to $C_{i,j}$ by the following equation.

$$C_{i,j} = 255\left(\frac{c_{i,j} - c_{\min}}{c_{\max} - c_{\min}}\right) \tag{3}$$

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

Next, compute the pixel values $f_{R,i,j}^{(t)}$, $f_{G,i,j}^{(t)}$ and $f_{B,i,j}^{(t)}$ by using the inverse iris filter as

$$f_{R,i,j}^{(t)} = a\left(f_{i,j}^{(t-1)} - IF\left(f_{i,j}^{(t-1)}\right)\right) + f_{R,i,j} \tag{4}$$

$$f_{G,i,j}^{(t)} = a\left(f_{i,j}^{(t-1)} - IF\left(f_{i,j}^{(t-1)}\right)\right) + f_{G,i,j} \tag{5}$$

$$f_{B,i,j}^{(t)} = a\left(f_{i,j}^{(t-1)} - IF\left(f_{i,j}^{(t-1)}\right)\right) + f_{B,i,j} \tag{6}$$

$$f_{i,j}^{(t-1)} = \frac{f_{R,i,j}^{(t-1)} + f_{G,i,j}^{(t-1)} + f_{B,i,j}^{(t-1)}}{3} \tag{7}$$

where a is positive constant and t is the number of iterations. Let the initial values $f_{R,i,j}^{(0)}$, $f_{G,i,j}^{(0)}$ and $f_{B,i,j}^{(0)}$ be $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$, respectively. The pixel values $f_{R,i,j}^{(t)}$, $f_{G,i,j}^{(t)}$ and $f_{B,i,j}^{(t)}$ are set to 0 if their values are less than 0, and set to 255 if their values are greater than 255.

Finally, cell-like color images are obtained after processing of the inverse iris filter of T times iteration.

3. **Experiments.** We first applied our method to the color image of $512 * 512$ size and 256 tone of Lena, and visually assessed the variations induced in cell-like color images by changing the parameters of the inverse iris filter. We next applied our method to several photographic color images of $512 * 512$ size and 256 tone.

3.1. **Effect of parameters on color image of Lena.** We first assessed the variation in cell-like color images generated by changing the number of iterations T with $r = 3$ and $a = 0.4$ in all cases. Figure 3 shows the results for $T = 1$, 5, 10 and 20. As T became bigger, cell patterns became clear and cell-like color image was converged. In order to converge cell-like color images, we judged that the optimal value of T was around 20.

We next assessed the variation in cell-like color images generated by changing r with $T = 20$ and $a = 0.4$ in all cases. Figure 4 shows the results for $r = 2$, 3, 4 and 5. As r became larger, each cell became bigger and blurred. In order to be able to visually recognize each cell for people and in order not to become blurred of each cell, we judged that the optimal value of r was around 3.

(a) $T = 1$ (b) $T = 5$ (c) $T = 10$ (d) $T = 20$

FIGURE 3. Variation in cell-like color images with iteration T

(a) $r = 2$ (b) $r = 3$ (c) $r = 4$ (d) $r = 5$

FIGURE 4. Variation in cell-like color images with r

(a) $a = 0.2$ (b) $a = 0.4$ (c) $a = 0.6$ (d) $a = 0.8$

FIGURE 5. Variation in cell-like color images with a

FIGURE 6. The enlarged view of cell-like color image with $T = 20$, $r = 3$ and $a = 0.4$

We finally assessed the variation in cell-like color images generated by changing a with $T = 20$ and $r = 3$ in all cases. Figure 5 shows the results for $a = 0.2$, 0.4, 0.6 and 0.8. As a became bigger, the lines between cells representing cell membrane became hard to see, but the region representing cell nucleus became clear. In order for a not to become too small and big, we judged that the optimal value of a was around 0.4.

For reference, Figure 6 shows the enlarged view of cell-like color image with $T = 20$, $r = 3$ and $a = 0.4$.

3.2. **Assessment with several images.** We applied our method to four photographic color images of $512 * 512$ size and 256 tone with $T = 20$, $r = 3$ and $a = 0.4$ in all cases.

(a) Balloon (b) Girl (c) Mandrill (d) Pepper

Figure 7. Photographic color images

(a) Balloon (b) Girl (c) Mandrill (d) Pepper

Figure 8. Cell-like color images

Figure 7 shows four photographic color images, and Figure 8 shows the results. In all four cases, cell-like color images were composed of cell patterns that were formed from the cell membrane and the cell nucleus, and were characterized to easily recognize the contour region since black cell patterns were arranged along the contour of the photographic color images. However, the cell patterns were less likely to appear in the white region of Figure 8(a), the black region of 8(b), and the small part of the texture of 8(c).

4. **Conclusions.** We proposed a novel non-photorealistic method for generating cell-like color images that were overlaid with cell patterns in photographic color images by incorporating the inverse iris filter. We demonstrated the effectiveness of our method through two experimental sets. The first set of experiments, performed with the color image of Lena, showed the variations that could be generated in cell-like color images by changing the parameters of the inverse iris filter. In the second set, we applied our method to several photographic color images and confirmed the visual effects of cell-like color images.

The future task is to generate cell patterns in the white region, the black region and the small part of the texture. Another task is to expand our method for application to motion images.

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