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Research Article

Generation of Labyrinth Images Using Gradients Between Circles in Window

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ABSTRACT
Non-photorealistic rendering methods to automatically generate labyrinth images from photographic images have been proposed. Labyrinth images are non-photorealistic images that maze-like intricate lines are laid out at approximately equal intervals on photographic images. Since the shape of the lines forming labyrinth images differs depending on the conventional method, it gives a different impression. We propose a method to generate labyrinth images composed of lines with a shape different from the conventional methods. The proposed method is performed by iterative computation with gradients between circles in a window. To verify the effectiveness of the proposed method, experiments were conducted to visually confirm labyrinth images generated from various photographic images.

1. Introduction

The advent of non-photorealistic rendering (NPR) [1], [2], [3], [4], [5], [6] in the 1990s created an interesting new field that favored representation, abstraction and stylization against traditional computer graphics for photorealism. By lifting the burden of realism, NPR is able to provide users with compelling and unique representations through abstraction and stylization. Many artistic and visual styles are enabled by NPR.

Many methods [7], [8], [9], [10] have been proposed to automatically generate labyrinth images from photographic images in one of NPRs. Labyrinth images are non-photorealistic images that maze-like intricate lines are laid out at approximately equal intervals on photographic images. The lines forming labyrinth images of the conventional methods have different shapes. Labyrinth images of the conventional methods [7], [8], [9], [10] consists of horizontal and vertical straight lines, straight lines that preserve the edges and have many bends that are close to right angles, curved lines along the edges, and curved lines along the edges and circular lines, respectively. Since different impressions can be given by different shapes of lines in labyrinth images, there is a demand for a method to generate labyrinth images composed of lines of other different shapes.

In this paper, we propose a method to generate labyrinth images that straight lines of the conventional method [8] are converted into smoother curved lines. The proposed method can generate lines with many bends close to right angles along the edges as well as the conventional method [8]. The proposed method is performed by iterative computation with gradients between circles in a window.

This paper is organized as follows: the second section describes the proposed method to generate labyrinth images from photographic images, 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. Proposed method

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The proposed method is implemented in three steps using gray-scale photographic images as input. Step 1 computes the gradients between the circles in the window. Step 2 transforms the photographic images using the gradients computed in Step 1. Steps 1 and 2 are computed repeatedly. Step 3 generates labyrinth images using the repeatedly calculated results. The flow chart of computed method is shown in Fig. 1.

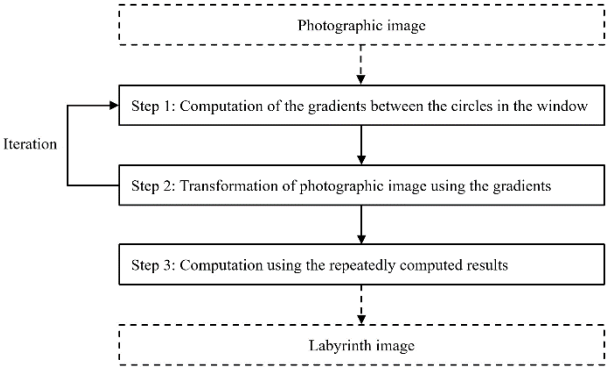


Fig 1 Flow chart of our method

The detailed procedure of the proposed method is as follows.

Step 0: The input pixel values for the coordinates (i, j) of a grayscale photographic image are denoted by $f_{i,j}$. The pixel values $f_{i,j}$ have values of U gradation from 0 to $U-1$. The pixel values of the image at the t-th iteration number are denoted by $f_{i,j}^{(t)}$, where $f_{i,j}^{(0)} = f_{i,j}$.

Step 1: The circle averages $a_{k,i,j}^{(t)}$ of the pixel values $f_{i,j}^{(t-1)}$ of the pixels whose distance is greater than or equal to $k(= 0, 1, 2, \cdots, K)$ and less than $k+1$ are calculated. The values $g_{k,i,j}^{(t)}$ are calculated from the circle averages $a_{k,i,j}^{(t)}$ in the following equation:

$$g_{k,i,j}^{(t)} = a_{k,i,j}^{(t)} - a_{k+1,i,j}^{(t)} \quad (1)$$

where k in $g_{k,i,j}^{(t)}$ is an integer value from 0 to $K-1$. The gradients $g_{i,j}^{(t)}$ are calculated from the values $g_{k,i,j}^{(t)}$ in the following equation:

$$g_{i,j}^{(t)} = \frac{\sum_{k=0}^{K-1} g_{k,i,j}^{(t)}(k+1)}{\sum_{k=0}^{K-1}(k+1)} \quad (2)$$

Step 2: The pixel values $f_{i,j}^{(t)}$ are calculated from the input pixel values $f_{i,j}$ using the gradients $g_{i,j}^{(t)}$ in the following equation:

$$f_{i,j}^{(t)} = f_{i,j} + \alpha g_{i,j}^{(t)} \quad (3)$$

where α is a positive constant. The pixel values $f_{i,j}^{(t)}$ must be set to $U-1$ if $f_{i,j}^{(t)}$ is greater than $U-1$, and $f_{i,j}^{(t)}$ must be set to 0 if $f_{i,j}^{(t)}$ is less than 0.

Step 3: Steps 1 and 2 are repeated T times. The pixel values $f_{i,j}^{(T)}$ must be set to $f_{i,j}$ if $f_{i,j}^{(T)}$ is greater than $(U-1)/2$, and $f_{i,j}^{(T)}$ must be set to 0 if $f_{i,j}^{(T)}$ is less than or equal to $(U-1)/2$. An image composed of the pixel values $f_{i,j}^{(T)}$ is a labyrinth image.

2. Experiments

Two experiments were conducted. The first experiment with changing the values of the parameters in the proposed method was conducted using Woman image shown in Fig. 2, and the way of generation of labyrinth patterns was confirmed visually. The second experiment was conducted using various photographic images shown in Fig. 3, and labyrinth images were confirmed visually. All photographic images used in the experiments comprised 512 * 512 pixels and 256 gradations.

Fig 2 Woman image

Fig. 3 Various photographic images

2.1. Experiment with changing parameters

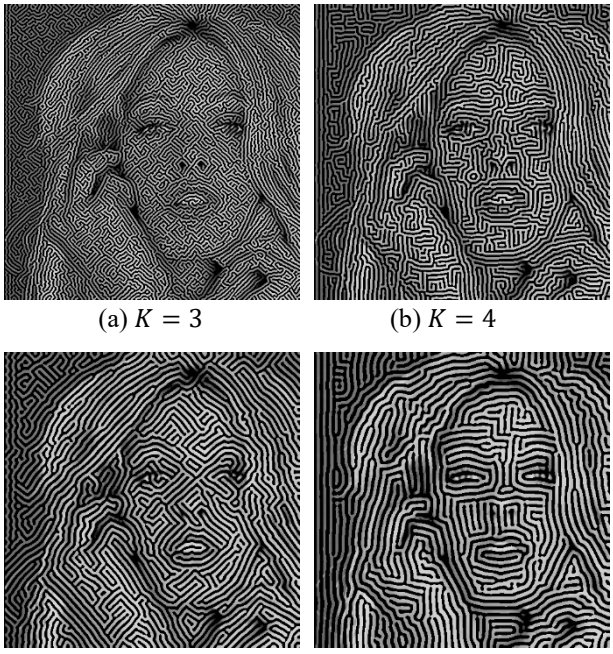
Labyrinth images generated by changing the value of the parameter T were visually confirmed using Woman image. The value of T was set to 5, 10, 20 and 40. The values of the parameters K and α were set to 4 and 6, respectively. Labyrinth images generated under these conditions are shown in Fig. 4. As the value of T was larger, labyrinth patterns became clearer and were expressed finely.

Labyrinth images generated by changing the value of the parameter K were visually confirmed using Woman image. The value of K was set to 3, 4, 5 and 6. The values

(a) $T = 5$ (b) $T = 10$

(c) $T = 20$ (d) $T = 40$

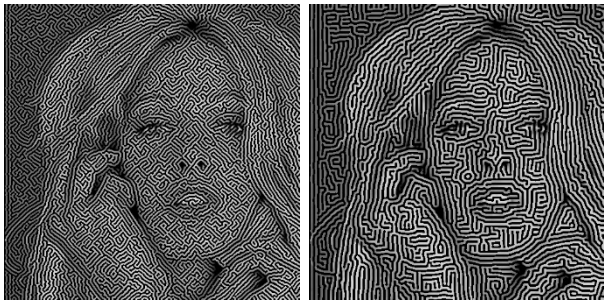
Fig. 4 Labyrinth images generated by changing the parameter T



(a) $K = 3$ (b) $K = 4$

(c) $K = 5$ (d) $K = 6$

Fig. 5 Labyrinth images generated by changing the parameter K



(a) $\alpha = 4$ (b) $\alpha = 6$

(c) $\alpha = 8$ (d) $\alpha = 10$

Fig. 6 Labyrinth images generated by changing the parameter α

of the parameters T and α were set to 40 and 6, respectively. Labyrinth images generated under these conditions are shown in Fig. 5. The larger the value of K, the larger labyrinth patterns.

Labyrinth images generated by changing the value of the parameter α were visually confirmed using Woman image. The value of α was set to 4, 6, 8 and 10. The values of the parameters T and K were set to 40 and 4, respectively. Labyrinth images generated under these conditions are shown in Fig. 6. The larger the value of α, the more bending of labyrinth patterns.

2.2. Experiment using various photographic images

The proposed method was applied to four photographic images shown in Fig. 3. The values of the parameters T, K and α were set to 40, 4 and 6, respectively. Labyrinth images generated under these conditions are shown in Fig. 7. All labyrinth images had lines with many bends close to right angles along the edges and had smoother curved lines than the conventional method [8].

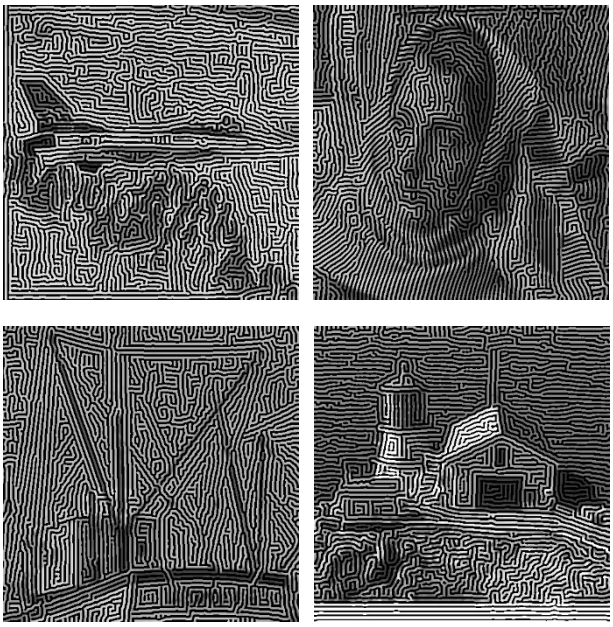


Fig. 7 Labyrinth images

3. Conclusions

We proposed a new NPR method to automatically generate labyrinth images from photographic images. The proposed method was performed by iterative computation with gradients between circles in a window. To visually confirm labyrinth images generated by the proposed method, we conducted an experiment using various photographic images. As a result of the experiment, labyrinth images had lines with many bends close to right angles along the edges and had smoother curved lines than the conventional method [8]. Additionally, we conducted an experiment to visually verify how labyrinth images changed by changing the values of the parameters in the proposed method.

Future studies include extending the proposed method to applications involving color photographic images, videos, and three-dimensional data.

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Authors Introduction

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