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GENERATION OF CONTOUR-LIKE IMAGES USING EUCLIDEAN DISTANCE FROM EDGES

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Abstract. *A non-photorealistic rendering method has been proposed to generate contour-like images from photographic images using smoothing filter and Laplacian filter. Contour-like images are non-photorealistic images obtained by overlaying contour lines used in map expressions on photographic images. However, contour-like images generated by the conventional method are difficult to see because contour-like patterns near the edges of photographic images are dense, complex and tangled. Therefore, we develop a method to make it easy to see contour-like patterns near the edges using distance images from the edges. We verified the effectiveness of our method through an experiment using various photographic images. In addition, we investigated the change in contour-like patterns through an experiment with different values of the parameter of our method. Experimental results showed that we can adjust the density of contour-like patterns and keep contour-like patterns from getting tangled.*
Keywords: Non-photorealistic rendering, Contour line, Distance image, Smoothing filter, Laplacian filter

1. **Introduction.** Many studies on non-photorealistic rendering (NPR) [1, 2, 3, 4, 5, 6] using image processing [7, 8] have been conducted so far. In recent years, studies on NPR that incorporates geometric patterns in society or nature have also been conducted [9, 10, 11, 12, 13, 14]. In NPR that incorporates geometric patterns in society or nature, maze-like images were generated by using minimum spanning trees [9], Truchet-like tiles were used for single-tone line-based rendering of maps [10], the mathematical model used in biology (the model of reaction-diffusion) was used as a new method of tonal depiction [11], cell-like images were generated by inverse iris filter [12], contour-like images were generated by smoothing filter and Laplacian filter [13], and zebra-pattern images were generated using smoothing filter and unsharp mask [14].

In NPR incorporating these social or natural geometric patterns, we focus on contour-like images [13]. Contour-like images are non-photorealistic images obtained by overlaying contour lines used in map expressions on photographic images. In the conventional method [13], contour-like patterns are fine and complex in the vicinity of the edges of photographic images, and the space between contour-like patterns is widely expressed in the regions where the change in shading is small. For these reasons, it is difficult to visually recognize contour-like patterns in the vicinity of the edges, and the valance between the wide and narrow spaces of contour-like patterns is deteriorated as a whole image. Therefore, if contour-like patterns in the vicinity of the edges are easily visible and the space between contour-like patterns is adjusted as the whole image, the expression of contour-like images is improved.

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By improving the conventional method [13], we develop a method for making contour-like patterns in the vicinity of the edges easier to visually recognize and for adjusting the space of contour-like patterns as the whole image. Our method is implemented using distance images from the edges. We conducted an experiment to adjust the space of contour-like patterns by changing the parameter value of our method using Lenna image, and then visually checked the balance between the wide and narrow spaces of contour-like patterns as the whole image. In addition, we conducted an experiment to apply our method to various photographic images, and then visually confirmed contour-like images. Experimental results show that our method works effectively.

This paper is organized as follows: the second section describes our method for generating contour-like images using distance 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. **Our Method.** Our method extends the conventional method [13] using distance images from the edges. Our method is performed in three steps: distance images are smoothed by smoothing filter in the first step, contour-like patterns are extracted from smoothed distance images by Laplacian filter in the second step, and contour patterns are overlaid on photographic images. By using the distance image, in the vicinity of the edges where the pixel values change greatly, the pixel values can be changed smoothly, and then fine and complicated contour-like patterns generated in vicinity of the edges can be generated in a larger space. And, since the distance image has constant changes in the pixel values, contour-like patterns in the same space are generated. Furthermore, since our method creates the distance image and executes substantially the same processing as the conventional method [13], the computational complexity is the same as the conventional method [13]. A flow chart of our method is shown in Figure 1.

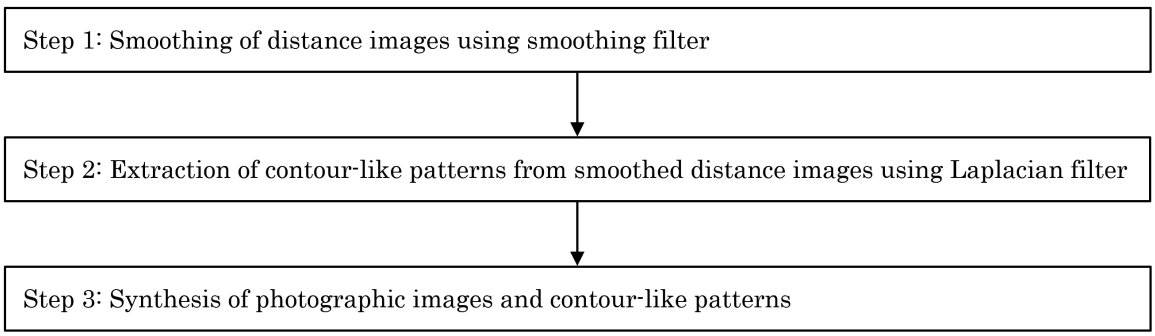


FIGURE 1. Flow chart of our method

The input pixel values for spatial coordinates (i, j) of a gray-scale photographic image are established as $f_{i,j}$. The pixel values $f_{i,j}$ have value of U gradation from 0 to $U-1$. The edges are extracted from the photographic image using EDISON [15] that is a feature extraction tool that integrates edge detection and image segmentation. The shortest Euclidean distances $D_{i,j}$ to the edge pixels are calculated at each pixel. The pixel values $d_{i,j}$ of a distance image are calculated by the following equation.

$$d_{i,j} = \begin{cases} a\dfrac{(U-1)(D_{\max} - D_{i,j})}{D_{\max}} & (D_{i,j} \neq 0) \\ U-1 & (D_{i,j} = 0) \end{cases} \tag{1}$$

where $D_{\max}$ is the maximum value in the Euclidean distances $D_{i,j}$, and a is a positive constant. As the value of a is small, the space between contour-like patterns in the regions where the change in shading is small becomes wide, and the space between contour-like

patterns in the vicinity of the edges becomes narrow. Conversely, as the value of a is large, the space between contour-like patterns in the regions where the change in shading becomes small becomes narrow, and the space between contour-like patterns in the vicinity of the edges is wide.

In the first step, the smoothed pixel values $g_{i,j}^{(t)}$ are calculated from the pixel values $d_{i,j}^{(t-1)}$ by smoothing filter, where t is the iteration number and $d_{i,j}^{(0)} = d_{i,j}$. The calculation is provided in the following equation.

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

where W is the window size, and k and l are the positions in the window. The above process is repeated T times.

In the second step, the pixel values $h_{i,j}$ of contour-like patterns are extracted by Laplacian filter from the pixel values $g_{i,j}^{(T)}$. The calculation is provided in the following equation.

$$h'_{i,j} = g_{i-1,j-1}^{(T)} + g_{i,j-1}^{(T)} + g_{i+1,j-1}^{(T)} + g_{i-1,j}^{(T)} - 8g_{i,j}^{(T)} + g_{i+1,j}^{(T)} + g_{i-1,j+1}^{(T)} + g_{i,j+1}^{(T)} + g_{i+1,j+1}^{(T)} \tag{3}$$

$$h_{i,j} = \begin{cases} 255\dfrac{h'_{i,j}}{h'_{\min}} & \left(h'_{i,j} < 0\right) \\ 255\dfrac{h'_{i,j}}{h'_{\max}} & \left(h'_{i,j} \geq 0\right) \end{cases} \tag{4}$$

where $h'_{\min}$ and $h'_{\max}$ are minimum and maximum values in $h'_{i,j}$, respectively.

In the third step, the pixel values $o_{i,j}$ after overlaying the contour-like patterns on the gray-scale photographic image are calculated in the following equation.

$$o_{i,j} = f_{i,j} + h_{i,j} \tag{5}$$

where $o_{i,j}$ must be set to $U-1$ if $o_{i,j}$ is greater than $U-1$. An image composed of pixel values $o_{i,j}$ is a contour-like image generated by our method.

3. **Experiments.** Two experiments were conducted: the change of the space of contour-like patterns generated by changing the value of the parameter a was visually confirmed using Lenna image shown in Figure 2 in the first experiment, and contour-like images generated from various photographic images shown in Figure 3 were visually confirmed in the second experiment. All photographic images used in the experiments were $512 * 512$ pixels and 256 gradation. For the experiments, referring to [13], the values of the parameters W and T were set as 6 and 10, respectively. For reference, the distance image of Lenna is shown in Figure 4.

In the first experiment, the change of the space of contour-like patterns generated by changing the value of the parameter a was visually confirmed using Lenna image. The value of a was set to 0.01, 0.1, 0.5 and 1.0. Contour-like images in these cases are shown

FIGURE 2. Lenna image

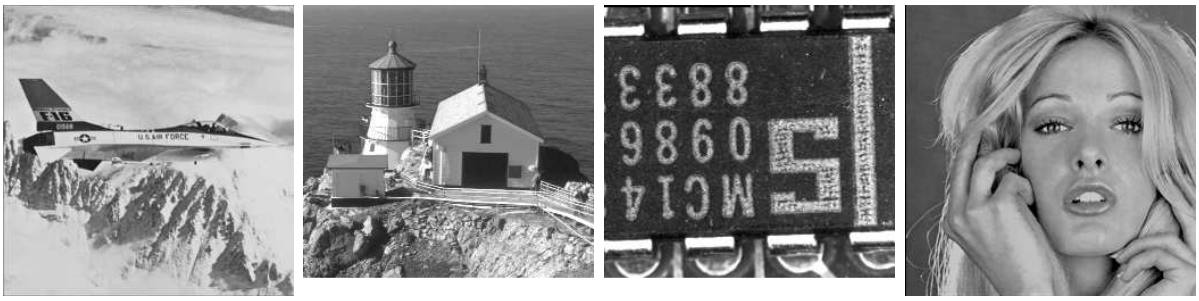


FIGURE 3. Photographic images

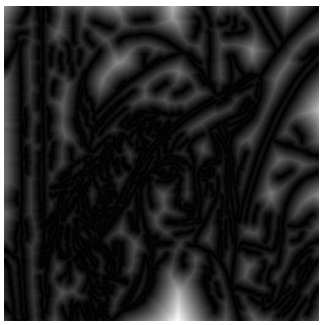
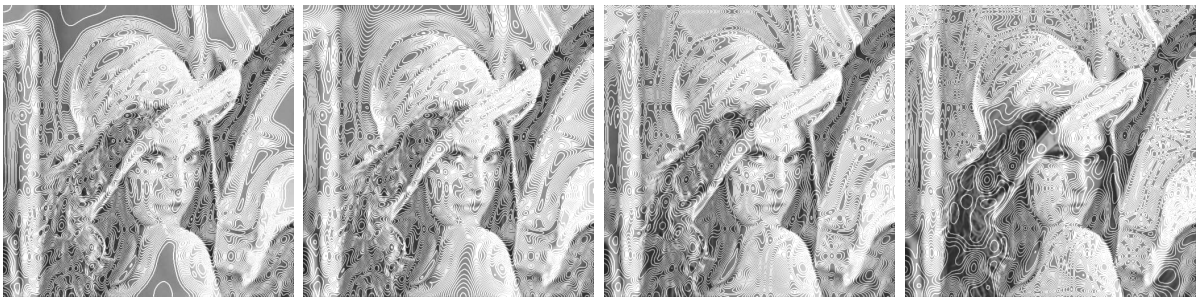


FIGURE 4. Distance image of Lenna image

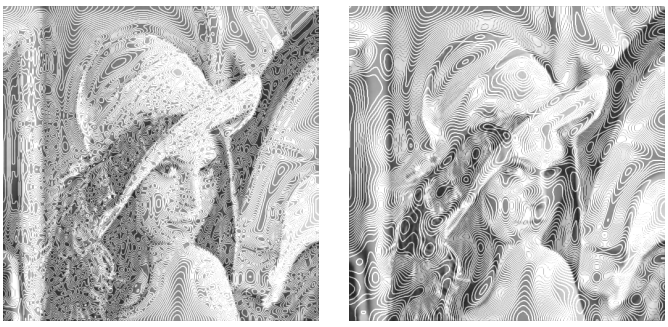


(a) $a = 0.01$ (b) $a = 0.1$ (c) $a = 0.5$ (d) $a = 1.0$

FIGURE 5. Contour-like images for $a = 0.01$, 0.1, 0.5 and 1.0

in Figure 5. Observing Figure 5, as the value of a was smaller, the space between contour-like patterns in the regions where the change in shading is small became wider, and the space between contour-like patterns in the vicinity of the edges became narrower. To generate contour-like images with the same space of contour-like patterns in the whole image and to make contour-like patterns in the vicinity of the edges easier to visually recognize, the value of a should be around 0.1 to 0.5. For reference, contour-like images in case of $a = 0.1$ and $W = 4, 8$ are shown in Figure 6. Observing Figure 6, the space of contour-like patterns became wider as the value of W was larger, but contour-like images with the same space of contour-like patterns were generated in the whole images.

In the second experiment, contour-like images generated from four photographic images were visually confirmed. Referring to the first experiment, the value of a was set to 0.1. Contour-like images generated from four photographic images are shown in Figure 7. Observing Figure 7, all contour-like images were balanced between the wide and narrow spaces of contour-like patterns as the whole image. For comparison, contour-like images generated from four photographic images by the conventional method [13] are shown in Figure 8. Contour-like images of the conventional method [13] had fine and complicated



(a) $W = 4$ (b) $W = 8$

FIGURE 6. Contour-like images for $W = 4$ and 8

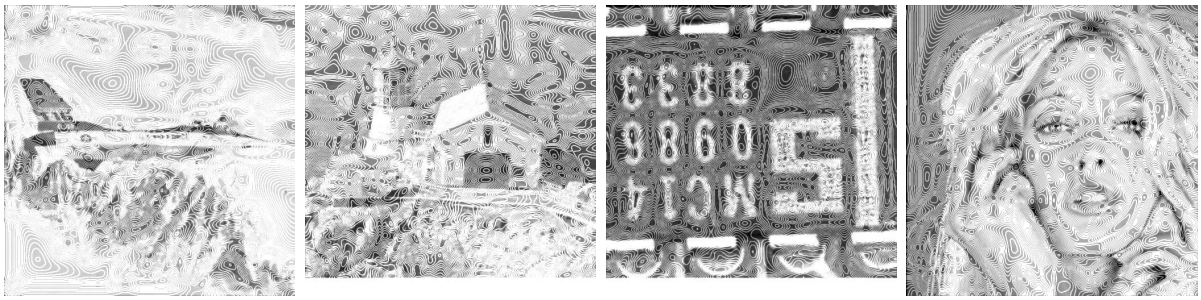


FIGURE 7. Contour-like images

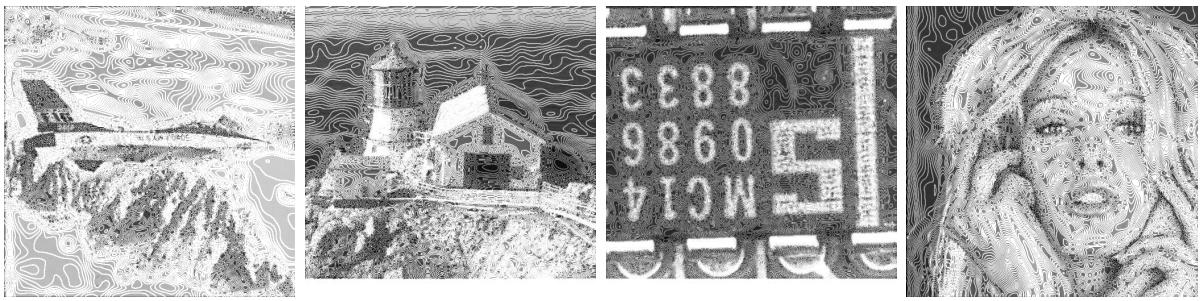


FIGURE 8. Contour-like images of the conventional method [13]

contour-like patterns in vicinity of the edges, but contour-like images of our method were improved.

4. **Conclusions.** An NPR method was developed in which contour-like images are generated from photographic images using distance images from the edges. Our method had features that contour-like patterns in the vicinity of the edges can be easily recognized and can adjust the space of contour-like patterns by changing the parameter value. To verify the effectiveness of our method, we investigated the change in contour-like patterns through an experiment with different values of the parameter. In addition, we verified the effectiveness of our method through an experiment using various photographic images. As a result of the experiments, our method could realize the above features.

A subject for future study is to expand our method for application to color photographic images and videos.

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