

Research Article

**GENERATION of Lines-Composed Images that Change
Brightness and Width of Lines**

Toru Hiraoka, Jia-Lin Zhang

Graduate School of Regional Design and Creation, University of Nagasaki, Japan

ARTICLE INFO

Article History

Received 20 May 2024

Accepted 29 May 2024

Keywords

Non-photorealistic rendering

Line

Brightness

Width

Different area

Automatic generation

ABSTRACT

We propose a non-photorealistic rendering method to automatically generate lines-composed images from photographic images. The brightness and width of the lines in lines-composed images change according to the change in the light and dark of photographic images. Our method is executed by repeating a process of updating images using the area near the target pixel that is the most different from the area centered on the target pixel. To verify the effectiveness of our method, we conducted experiments with changing the values of parameters in our method. The experimental results show that our method can generate impressive non-photorealistic images.

© 2022 The Author. Published by Sugisaka Masanori at ALife Robotics Corporation Ltd.

This is an open access article distributed under the CC BY-NC 4.0 license

[\(http://creativecommons.org/licenses/by-nc/4.0/\)](http://creativecommons.org/licenses/by-nc/4.0/).**1. Introduction**

Various studies on image processing and computer graphics have been conducted so far. Among these studies are studies on non-photorealistic rendering (NPR) that combines image processing and computer graphics. NPR can transmit visual information more effectively, and can generate images that are enhanced artistry and entertainment from photographic images, videos and three-dimensional data. Therefore, the non-photorealistic images are used in television, magazines and websites. The studies on NPR been conducted since around 1990, and NPR methods for generating non-photorealistic images of various expressions are currently being developed [1], [2], [3], [4], [5], [6]. In this paper, we develop a method to automatically generate lines-composed images as NPR of an unprecedented expression from photographic images. Lines-composed images are represented by lines, and the brightness and

width of the lines change according to the change in the light and dark of photographic images. In bright areas in photographic images, black lines are rendered thinner and brighter, and white lines are rendered wider and brighter. In dark areas in photographic images, black lines are rendered wider and darker, and white lines are rendered thinner and darker. Our method is implemented by an iterative processing using the area near the target pixel that is the most different from the area centered on the target pixel. By conducting an experiment using Lenna image, the appearance of lines-composed images generated by changing the values of the parameters in our method was visually clarified. In addition, an experiment was conducted to apply our method to various photographic images.

As a similar study, methods for generating striped images [7], [8] and labyrinth images [9], [10], [11], [12] have been proposed. When generating striped images, Weickert [7] used shock filter, and Hiraoka and Urahama

Corresponding author's E-mail: hiraoka@sun.ac.jp

[8] used inverse line convergence index filter. When generating labyrinth images, Pedersen and Singh [9] used differential equations, Sparavigna and Montrucchio [10] used tiling, Inoue and Urahama [11] used minimum spanning trees, and Hiraoka and Tsurunari used bilateral filter and unsharp mask. Our method uses the method different from the conventional methods. Although the brightness and width of striped and labyrinth patterns generated by the conventional methods are constant, our method can automatically change the brightness and width of line patterns according to the change in the light and dark of photographic images.

The rest of this paper is organized as follows. Section 2 describes our method to generate lines-composed images from photographic 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 lines-composed images from gray-scale photographic images. Our method is executed in three steps. In the first step, the area that is the most different from the area centered on the target pixel is found from around the target pixel. In the second step, processing using smoothing filter is performed. In the third step, processing using inverse filter [11], [14], is performed. Lines-composed images are generated by repeating the three steps. A flow chart of our method is shown in Fig. 1.

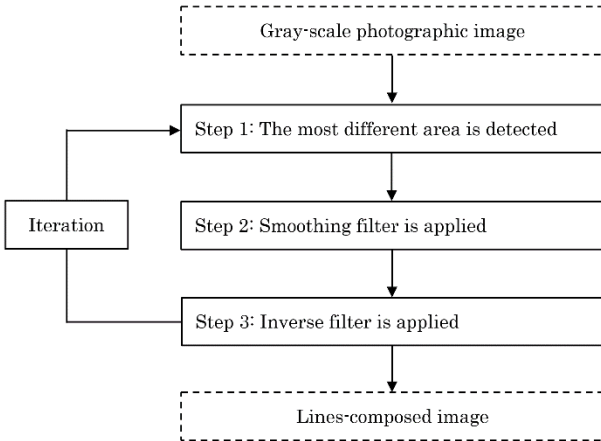


Fig 1 Flow chart of our method

Details of the procedure in Fig. 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 gradations from 0 to $U - 1$. Let the pixel values of the t -th iteration be $f_{i,j}^{(t)}$, where $f_{i,j}^{(0)} = f_{i,j}$.

Step 1: The difference $d_{i,j,k,l}^{(t)}$ between the pixel values in the windows centered on the target pixel (i, j) and the peripheral pixel (k, l) is computed as follows.

$$d_{i,j,k,l}^{(t)} = \sum_{m=-W}^W \sum_{n=-W}^W |f_{i+m,j+n}^{(t-1)} - f_{k+m,l+n}^{(t-1)}| \quad (1)$$

where W is the window size, and m and n are the positions in the window. For all pixels contained in the window of size W centered on the target pixel (i, j) , the differences $d_{i,j,k,l}^{(t)}$ are calculated, and let the maximum value among the differences $d_{i,j,k,l}^{(t)}$ be $d_{i,j,max}^{(t)}$.

Step 2: The pixel values $d_{i,j,max}^{(t)}$ are smoothed using pixel values in the window of size W . Let the smoothed pixel values be $s_{i,j}^{(t)}$ as follows.

$$s_{i,j}^{(t)} = \frac{\sum_{m=-W}^W \sum_{n=-W}^W d_{i+m,j+n,max}^{(t)}}{(2W+1)^2} \quad (2)$$

Step 3: The pixel values $f_{i,j}^{(t)}$ are computed using inverse filter as follows.

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

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 $U - 1$.

By repeating the processing of Step 1 to Step 3 T times, an image composed of the pixel values $f_{i,j}^{(T)}$ is the lines-composed image.

3. Experiments

We mainly conducted two experiments. The first experiment with changing the values of the parameters in our method was conducted using Lenna image shown in Fig. 2. The second experiment was conducted by applying our method to four photographic images shown in Fig. 3. All photographic images used in the experiments were 512 * 512 pixels and 256 gradations.



Fig 2. Lenna image



Fig. 3. Various photographic images

3.1. Experiment with changing parameters

We visually confirmed lines-composed images changed the value of the iteration number T using Lenna image. We set the value of T to 5, 10, 15 and 20, and set the value of W to 2. The results of the experiment with changing the value of T are shown in Fig. 4. As the value of T became large, lines-composed patterns became clear. The value of T should be 20 to generate clearly lines-composed patterns for photographic images of $512 * 512$ pixels.

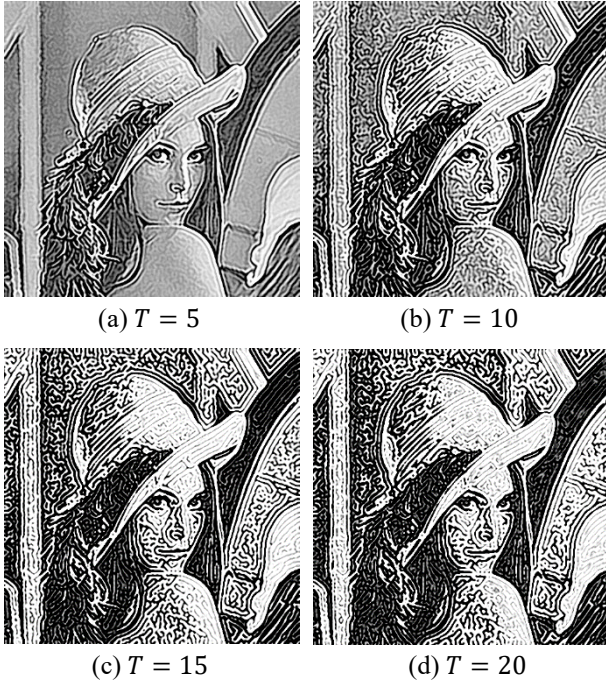


Fig. 4 Lines-composed images generated by changing the value of the iteration number T

We visually confirmed lines-composed images changed the value of the window size W using Lenna image. We set the value of W to 1, 2, 3 and 4, and set the value of T to 20. The results of the experiment with changing the value of W are shown in Fig. 5. As the value of W was larger, lines-composed patterns became wider. The value of W should be changed according to the usage application of the users.



Fig. 5. Lines-composed images generated by changing the value of the window size W

3.2. Experiment using various photographic images

Our method was applied to four photographic images shown in Fig. 3. Since lines-composed patterns were visually recognized well in the previous experiments, we set the values of the parameters T and W to 20 and 2, respectively. The results of the experiment are shown in Fig. 6. In all lines-composed images, lines-composed patterns could be changed in brightness and width according to the change in the light and dark of photographic images.

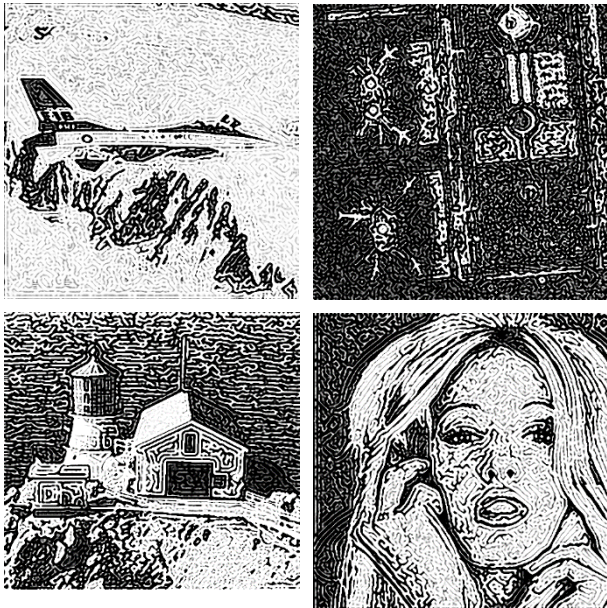


Fig. 6. Lines-composed images

4. Conclusions

We developed an NPR method to automatically generate lines-composed images from gray-scale photographic images. Our method was executed by an iterative processing using the area near the target pixel that is the most different from the area centered on the target pixel. To verify the effectiveness of our method, we visually confirmed lines-composed images by changing the values of the parameters, and conducted experiments using various photographic images. As a result of the experiments, it was clarified that the width of lines-composed patterns can be changed by changing the window size in our method. It also was found that our method can change brightness and width of lines-composed patterns according to the change in the light and dark of photographic images.

A subject for future study is to expand our method for application to color photographic images, videos and three-dimensional data.

Acknowledgment

This work was supported by JSPS KAKENHI Grant Number JP23K11727 and The Telecommunications Advancement Foundation Grant.

References

1. P. Haeberli. Paint by numbers: abstract image representations. *ACM SIGGRAPH Computer Graphics*, 1990, 24(4): 207-214.
2. J. Lansdown and S. Schofield. Expressive rendering: a review of nonphotorealistic techniques. *IEEE Computer Graphics and Applications*, 1995, 15(3): 29-37.
3. J. Correia, L. Vieira, N. Rodriguez-Fernandez, J. Romero and P. Machado. Evolving image enhancement pipelines. *Artificial Intelligence in Music, Sound, Art and Design*, 2021: 82-97.
4. P. L. Rosin, Y. K. Lai, D. Mould, R. Yi, I. Berger, L. Doyle, S. Lee, C. Li, Y. J. Liu, A. Semmo, A. Shamir, M. Son and H. Winnemoller, NPRportrait 1.0: A three-level benchmark for non-photorealistic rendering of portraits. *Computational Visual Media*, 2022, 8(3): 445-465.
5. Y. Zhao, D. Ren, Y. Chen, W. Jia, R. Wang and X. Liu. Cartoon image processing: A survey. *International Journal of Computer Vision*, 2022, 130(11): 2733-2769.
6. W. Ye, X. Zhu and Y. Liu. Multi-semantic preserving neural style transfer based on Y channel information of image. *The Visual Computer*, 2023, 39(2): 609-623.
7. J. Weickert. Coherence-enhancing shock filters. *Pattern Recognition Lecture Notes in Computer Science*, 2003, 2781: 1-8.
8. T. Hiraoka and K. Urahama. Generating striped color images by inverse line convergence index filter. *IEEE Transactions on Image Electronics and Visual Computing*, 2014, 2(2): 190-194.
9. H. Pedersen and K. Singh. Organic labyrinths and mazes. *Proceedings of the 4th International Symposium on Non-Photorealistic Animation and Rendering*, 2006: 76-86.
10. A. Sparavigna and B. Montrucchi. Non-photorealistic image rendering with a labyrinthine tiling. *Cornell University Library*, 2006, arXiv:cs/0609084.
11. K. Inoue and K. Urahama. Halftoning with Minimum spanning trees and its application to maze-like images. *ELSEVIER Computers & Graphics*, 2009, 33(5): 638-647.
12. Toru Hiraoka and Yoshihisa Tsurunari. Generation of maze-like images by bilateral filter and unsharp mask in HLS color space. *ICIC Express Letters*, 2021, 15(10): 1053-1059.
13. J. M. Ortega and W. C. Rheinboldt. Iterative solutions of nonlinear equations in several variables. *Society for Industrial Mathematics*, 1987.
14. Z. Yu and K. Urahama. Iterative method for inverse nonlinear image processing. *IEICE Transactions on Fundamentals*, 2014, E97-A(2): 719-721.

Authors Introduction

Dr. Toru Hiraoka



He received B.Des., M.Des. and D.Eng. degrees from Kyushu Institute of Design in 1995, 1997 and 2005, respectively. He is currently a Professor in University of Nagasaki. His research interests include non-photorealistic rendering and disaster prevention.

Mr. Jia-Lin Zhang



He is a student in the Graduate School of Regional Design and Creation, University of Nagasaki. His research interests include non-photorealistic rendering and image processing.