ICIC Express Letters
Volume **17**, Number **3**, March **2023**
 ISSN 1881-803X
pp. **375–380**

GENERATION OF MULTI-VALUED/OVERLAPPING YIN-YANG-PATTERN-LIKE IMAGES USING BIT PATTERN OF PIXEL VALUE

Toru Hiraoka

Department of Information Systems
University of Nagasaki
1-1-1, Manabino, Nagayo-chou, Nishisonogi-gun, Nagasaki-ken 851-2195, Japan
hiraoka@sun.ac.jp

Received June 2022; accepted September 2022

Abstract. *We propose a non-photorealistic rendering method for generating multi-valued/overlapping Yin-Yang-pattern-like (MOYYPL) images from gray-scale photographic images. Yin-Yang-pattern-like (YYPL) images are represented by smooth-curved black and white areas. MOYYPL images are represented by multi-valued areas, and MOYYPL patterns are represented by overlapping. The purpose of this paper is to generate MOYYPL images that improve the appearance of conventional YYPL images. The proposed method is executed by an iterative calculation using a bit pattern of pixel values. To verify the effectiveness of the proposed method, an experiment using various gray-scale photographic images was performed. In addition, the changes of MOYYPL patterns generated by changing the values of the parameters in the proposed method were visually confirmed. MOYYPL images generated by the proposed method gives an impression different from YYPL images generated by the conventional method.*
Keywords: Non-photorealistic rendering, Yin-Yang pattern, Multi value, Overlap, Bit pattern

1. **Introduction.** Many studies on non-photorealistic rendering (NPR) by image processing [1, 2] have been conducted so far [3, 4, 5, 6]. [3] reviewed an expressive system of NPR, [4] reviewed techniques for the digital simulation of hand-made stippling, [5] presented a course design on NPR, and [6] presented a benchmark dataset that is structured into three levels to provide clearly specified degrees of difficulty for NPR and neural style transfer. One of NPRs has proposed a method for generating Yin-Yang-pattern-like (YYPL) images from gray-scale photographic images [7, 8]. Yin-Yang patterns are designed by combining black and white areas, and YYPL images represent gray-scale photographic images in black and white areas having smooth curve such as Yin-Yang patterns. YYPL images generated by the conventional method [7], which was executed by an iterative calculation using a reversal inverse bilateral filter, had the disadvantage that fine patterns were generated and sharp-edged areas remained. Therefore, in the conventional method [8] which was executed by an iterative calculation using difference of Gaussian, YYPL images without leaving fine textures and sharp-edged areas were generated.

In this paper, we consider further improving the appearance of YYPL images. Therefore, the binary YYPL patterns of black and white are expanded to multi-valued YYPL patterns. In addition, the YYPL patterns that the black and white areas are separated are expanded to overlapping YYPL patterns. We propose a method for generating multi-valued/overlapping Yin-Yang-pattern-like (MOYYPL) images from gray-scale photographic images. The proposed method is executed by an iterative calculation using a bit pattern of pixel values, and uses windows of two sizes to express as fine MOYYPL

DOI: 10.24507/icicel.17.03.375

patterns as possible in rough MOYYPL patterns. The proposed method can automatically generate MOYYPL patterns according to the change of the edges and the shading in gray-scale photographic images. Through an experiment that the proposed method was applied to various gray-scale photographic images, it was visually confirmed that MOYYPL patterns were generated. In addition, through an experiment of changing the values of the parameter in the proposed method, how to change MOYYPL patterns was clarified.

This paper is organized as follows: the second section describes the proposed method for generating MOYYPL images from gray-scale photographic images, the third section shows experimental results and reveals the effectiveness of the proposed method, and the conclusion of this paper is given in the fourth section.

2. **Proposed Method.** The proposed method is implemented in three steps. The first step performs the calculation using the bit pattern for each of the windows of two sizes. The second step updates the image from the values calculated in the two windows. MOYYPL patterns are generated by repeating the first and second steps. To make the MOYYPL patterns more recognizable to humans, the third step performs the histogram equalization to generate the final MOYYPL images. A flow chart of the proposed method is shown in Figure 1.

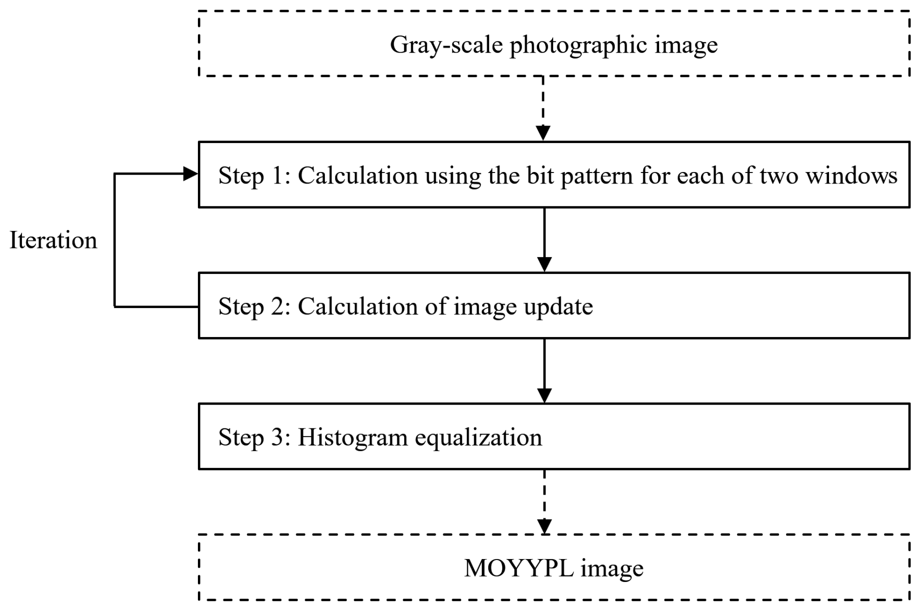

FIGURE 1. Flow chart of the proposed method

Details of the procedure in Figure 1 are explained below.

Step 0: The input pixel values for spatial coordinates (i, j) of a gray-scale photographic image are defined as $f_{i,j}$. Then, the pixel values of the image at the t-th iteration number are defined as $f_{i,j}^{(t)}$, where $f_{i,j}^{(0)} = f_{i,j}$. The pixel values $f_{i,j}^{(t)}$ have value of 256 gradation from 0 to 255. The pixel values $f_{i,j}^{(t)}$ are represented by 8 bits, and the 8-bit representations are defined as $b_{i,j,k}^{(t)}$ where $b_{i,j,k}^{(t)} = \{0, 1\}$ and $k = 0, 1, \ldots, 7$. The pixel values $f_{i,j}^{(0)}$ and the 8-bit representations $b_{i,j,k}^{(0)}$ have the following relationship.

$$f_{i,j}^{(0)} = \sum_{k=0}^{7} 2^k b_{i,j,k}^{(0)} \tag{1}$$

Step 1: The numbers $c_{i,j,k,1}^{(t)}$ are calculated in the pixels in the window of window size W_1 as

$$c_{i,j,k,1}^{(t)} = \sum_{m=-W_1}^{W_1} \sum_{n=-W_1}^{W_1} b_{i+m,j+n,k}^{(t-1)} \tag{2}$$

where m and n are the positions in the window. In case the numbers $c_{i,j,k,1}^{(t)}$ are less than $(2W_1+1)^2/2$, then the 8-bit representations $b_{i,j,k,1}^{(t)}$ must be set to 0. In case the numbers $c_{i,j,k,1}^{(t)}$ are greater than $(2W_1+1)^2/2$, then the 8-bit representations $b_{i,j,k,1}^{(t)}$ must be set to 1. The pixel values $f_{i,j,1}^{(t)}$ are calculated as

$$f_{i,j,1}^{(t)} = \sum_{k=0}^{7} 2^k b_{i,j,k,1}^{(t)} \tag{3}$$

Similarly, the numbers $c_{i,j,k,2}^{(t)}$ are calculated in the pixels in the window of window size W_2 where $W_1 \leq W_2$ as

$$c_{i,j,k,2}^{(t)} = \sum_{m=-W_2}^{W_2} \sum_{n=-W_2}^{W_2} b_{i+m,j+n,k}^{(t-1)} \tag{4}$$

In case the numbers $c_{i,j,k,2}^{(t)}$ are less than $(2W_2+1)^2/2$, then the 8-bit representations $b_{i,j,k,2}^{(t)}$ must be set to 0. In case the numbers $c_{i,j,k,2}^{(t)}$ are greater than $(2W_2+1)^2/2$, then the 8-bit representations $b_{i,j,k,2}^{(t)}$ must be set to 1. The pixel values $f_{i,j,2}^{(t)}$ are calculated as

$$f_{i,j,2}^{(t)} = \sum_{k=0}^{7} 2^k b_{i,j,k,2}^{(t)} \tag{5}$$

Step 2: The pixel values $f_{i,j}^{(t)}$ are calculated as

$$f_{i,j}^{(t)} = \frac{f_{i,j,1}^{(t)} + f_{i,j,2}^{(t)}}{2} \tag{6}$$

The 8-bit representations $b_{i,j,k}^{(t)}$ are calculated from the pixel values $f_{i,j}^{(t)}$.

Steps 1 and 2 are repeated T times. MOYYPL patterns become clearer as the number of repetitions increases.

Step 3: An MOYYPL image is generated by performing the histogram equalization on the image having the pixel values $f_{i,j}^{(T)}$. The histogram equalization is the process of converting the pixel values so that the overall histogram of the pixel values is unpleasant.

3. **Experiments.** Two experiments were conducted. The first experiment visually checked the changes of MOYYPL patterns when the values of the parameters in the proposed method were changed using the woman image shown in Figure 2. The second experiment applied the proposed method to four gray-scale photographic images shown in Figure 3. All photographic images used in the experiments were $256 * 256$ pixels and 256 gradation. The computing environment for all experiments is a Windows 10 Enterprise 2016 LTSB operating system on a computer with a 3.20 GHz CPU and a 8.00 GB memory. The programming language used is VC++.

FIGURE 2. Woman image

FIGURE 3. Various gray-scale photographic images

(a) $T = 5$ (b) $T = 10$ (c) $T = 20$ (d) $T = 40$

FIGURE 4. MOYYPL images in the case of the iteration number $T = 5$, 10, 20 and 40

3.1. **Experiment with changing parameters.** MOYYPL images by changing the iteration number T were visually confirmed using the woman image. The iteration number T was set to 5, 10, 20 and 40. The parameters W_1 and W_2 were set to 1 and 3, respectively. The results of the experiment are shown in Figure 4. As the iteration number T increased, MOYYPL patterns were clear.

MOYYPL images by changing the window size W_1 were visually confirmed using the woman image. The window size W_1 was set to 0, 1, 2 and 3. The parameters T and W_2 were set to 40 and 3, respectively. The results of the experiment are shown in Figure 5. As the window size W_1 became larger, MOYYPL patterns were larger and smoother. On the other hand, as the window size W_1 became larger, the woman image became more difficult to recall.

MOYYPL images by changing the window size W_2 were visually confirmed using the woman image. The window size W_2 was set to 2, 3, 4 and 5. The parameters T and W_1 were set to 40 and 1, respectively. The results of the experiment are shown in Figure 6. As the window size W_2 became larger, MOYYPL patterns were larger and smoother. On

(a) $W_1 = 0$ (b) $W_1 = 1$ (c) $W_1 = 2$ (d) $W_1 = 3$

FIGURE 5. MOYYPL images in the case of the window size $W_1 = 0$, 1, 2 and 3

(a) $W_2 = 2$ (b) $W_2 = 3$ (c) $W_2 = 4$ (d) $W_2 = 5$

FIGURE 6. MOYYPL images in the case of the window size $W_2 = 2$, 3, 4 and 5

the other hand, as the window size W_2 became larger, the woman image became more difficult to recall.

3.2. **Experiment using various photographic images.** The proposed method was applied to four gray-scale photographic images shown in Figure 3. The parameters T, W_1 and W_2 were set to 40, 1 and 3, respectively. The results of the experiment are shown in Figure 7. All MOYYPL images could be automatically generated according to the change of the edges and the shading in gray-scale photographic images. In addition, the proposed method could generate MOYYPL patterns with multi-valued/overlapping YYPL patterns in all MOYYPL images.

YYPL images generated from four gray-scale photographic images by the conventional method [8] are shown in Figure 8 for comparison with MOYYPL images. Since YYPL images were expressed by the binary values of black and white, it was difficult to recall

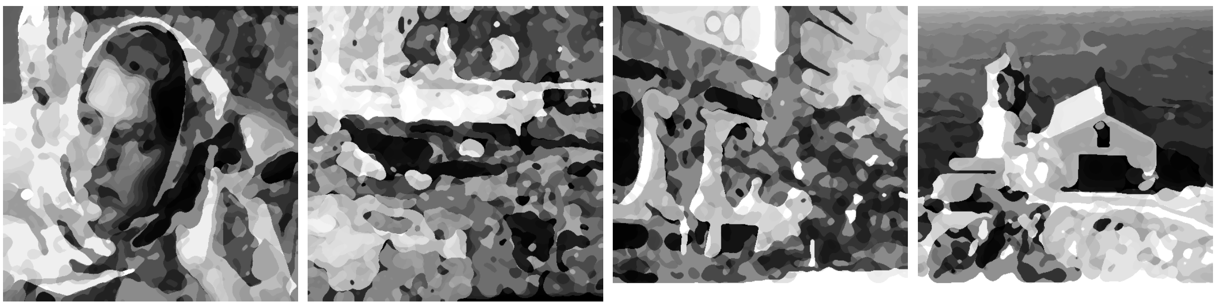

FIGURE 7. Various MOYYPL images

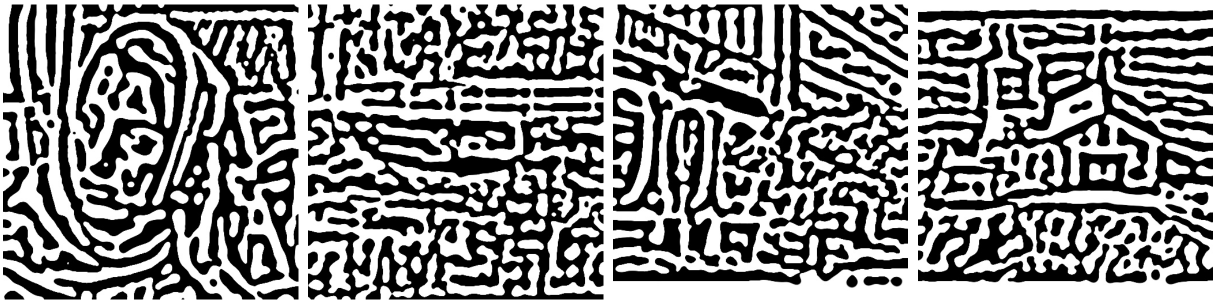

Figure 8. Various YYPL images

photographic images. On the other hand, since MOYYPL images were expressed by multiple values, it is easier to recall photographic images. In addition, the shapes of MOYYPL patterns and YYPL patterns were expressed differently.

Finally, the calculation time of the proposed method and the conventional method [8] was compared. It took about 22 seconds to generate MOYYPL images of Figure 7 and about 64 seconds to generate YYPL images of Figure 8. Thus, the proposed method could process faster than the conventional method [8].

4. **Conclusions.** We proposed an NPR method for generating MOYYPL images from gray-scale photographic images. The proposed method was executed by an iterative calculation using a bit pattern of pixel values. Through an experiment that the proposed method was applied to various gray-scale photographic images, it was visually confirmed that MOYYPL patterns were generated. In addition, through an experiment of changing the values of the parameter in the proposed method, how to change MOYYPL patterns was clarified.

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

Acknowledgment. This work was supported by JSPS KAKENHI Grant Number JP19K 12664.

REFERENCES

[1] Y. Zhao and Q. Huang, Image enhancement of robot welding seam based on wavelet transform and contrast guidance, *International Journal of Innovative Computing, Information and Control*, vol.18, no.1, pp.149-159, 2022.

[2] D. Wang, Y. Ma, Z. Pan and N. Zhang, Enhancement for low-contrast images with FitzHugh-Nagumo nonlinearity and adaptive stochastic resonance, *International Journal of Innovative Computing, Information and Control*, vol.18, no.3, pp.941-955, 2022.

[3] J. Lansdown and S. Schofield, Expressive rendering: A review of nonphotorealistic techniques, *IEEE Computer Graphics and Applications*, vol.15, no.3, pp.29-37, 1995.

[4] D. Martin, G. Arroyo, A. Rodriguez and T. Isenberg, A survey of digital stippling, *Computers & Graphics*, vol.67, pp.24-44, 2017.

[5] I. Ilinkin, Designing a course on non-photorealistic rendering, *Eurographics 2020*, pp.9-16, 2020.

[6] 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*, vol.8, no.3, pp.445-465, 2022.

[7] T. Hiraoka and M. Kumano, Generating Yin and Yang pattern-like images using reversal inverse bilateral filter, *Journal of the Japan Association for College of Technology*, vol.21, no.1, pp.51-54, 2016.

[8] T. Hiraoka, Generation of Yin-Yang-pattern-like images by iterative calculation using DoG, *Journal of the Institute of Industrial Applications Engineers*, vol.9, no.4, pp.115-118, 2021.