

Generation of Yin-Yang-Pattern-Like Images by Iterative Calculation Using DoG

TORU HIRAOKA^{*†} Member

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Abstract: We propose a non-photorealistic rendering method that converts photographic images into Yin-Yang-pattern-like images are represented by smooth curved black and white areas. The proposed method applies two Gaussian filters with different parameter values (Difference of Gaussian: DoG) to photographic images, calculates the difference between the two smoothed images, and adds the difference to photographic images. By repeating the process, Yin-Yang-pattern-like images are generated. In order to verify the effectiveness of the proposed method, we performed an experiment using Lenna image, and visually confirmed the changes of Yin-Yang-pattern-like images generated when the values of the various parameters were changed. In addition, we performed an experiment using various photographic images.

Keywords: Non-photorealistic rendering, Yin-Yang pattern, Iterative calculation, DoG

1. Introduction

In recent years, non-photorealistic rendering (NPR) has attracted attention [1]~[7]. NPR is a rendering technique that does not pursue the reality of the conventional realistic rendering but dares to omit or exaggerate information like painting or illustration. In addition to NPR that mimics traditional art expressions, NPR methods that pursue new expressions have been proposed: maze-like images [8] [9], op-art images [10] [11], reaction-diffusion images [12] [13], line-pattern images [14], contour-like images [15], moire-like images [16] and Yin-Yang-pattern-like (YYPL) images [17].

This paper focuses on YYPL images. Yin-Yang patterns are design combining black and white areas shown in Figure 1. YYPL images express photographic images in black and white areas having smooth curve such as Yin-Yang patterns, have few fine textures, and can be visually recognized photographic images. The conventional method [17] generates YYPL images from photographic images using bilateral filter [18] [19] and reversal inverse bilateral filter [20], and has the disadvantage that fine textures and sharp-edged areas remain.

Therefore, we propose a method that can generate YYPL images without leaving fine textures and sharp-edged areas. The proposed method is executed by an iterative calculation using difference of Gaussian (DoG). The proposed method could automatically generate YYPL images according to the change of the edges and the shading in photographic images. A method for generating pencil-shading, pastel, hatching and woodcut as NPR using Dog has been proposed

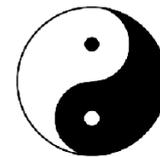


Figure 1: Yin-Yang pattern.

[21], but the proposed method is different from the conventional method [21] because it generates YYPL images. In order to verify the effectiveness of the proposed method, we conduct an experiment using various photographic images, and visually check that fine textures and sharp-edged areas do not occur in YYPL images. In addition, we visually check the changes in YYPL images generated by changing the values of the various parameters in the proposed method.

This paper is organized as follows: the second section describes the proposed method for generating YYPL images from 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 two steps: the first step is to calculate the difference between two images that are applied two smoothing filters with different parameter values, and the second step is to add the difference to the image before smoothing. The first process is by DoG. By repeating the two steps, YYPL image is generated. A flow chart of the proposed method is shown in Figure 2.

Details of the procedure in Figure 2 are explained below.

Step 0 The input pixel values for spatial coordinates (i, j)

* Corresponding: hiraoka@sun.ac.jp

† Faculty of Information System, University of Nagasaki
Nagasaki-ken, 851-2195 Japan

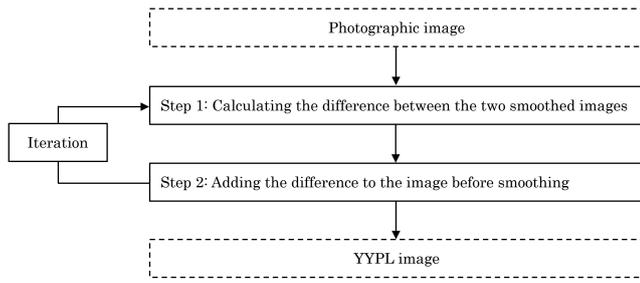


Figure 2: Flow chart of the proposed method.

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 $f_{i,j}^{(1)} = f_{i,j}$. The pixel values $f_{i,j}^{(t)}$ have value of U gradation from 0 to $U - 1$.

Step 1 The pixel values $f_{i,j}^{(t)}$ are respectively smoothed to the pixel values $s_{1,i,j}^{(t)}$ and $s_{2,i,j}^{(t)}$ with different parameter values α_1 and α_2 ($\alpha_1 > \alpha_2$) as

$$s_{1,i,j}^{(t)} = \frac{\sum_{k=-W}^W \sum_{l=-W}^W e^{-\alpha_1((i-k)^2+(j-l)^2)} f_{i+k,j+l}^{(t)}}{\sum_{k=-W}^W \sum_{l=-W}^W e^{-\alpha_1((i-k)^2+(j-l)^2)}} \quad (1)$$

$$s_{2,i,j}^{(t)} = \frac{\sum_{k=-W}^W \sum_{l=-W}^W e^{-\alpha_2((i-k)^2+(j-l)^2)} f_{i+k,j+l}^{(t)}}{\sum_{k=-W}^W \sum_{l=-W}^W e^{-\alpha_2((i-k)^2+(j-l)^2)}} \quad (2)$$

where W is the window size, and k and l are the positions in the window. The differences $d_{i,j}^{(t)}$ between the smoothed pixel values $s_{1,i,j}^{(t)}$ and $s_{2,i,j}^{(t)}$ are calculated as

$$d_{i,j}^{(t)} = s_{1,i,j}^{(t)} - s_{2,i,j}^{(t)} \quad (3)$$

Step 2 The pixel values $f_{i,j}^{(t+1)}$ are calculated by adding the differences $d_{i,j}^{(t)}$ to the pixel values $f_{i,j}^{(t)}$ as

$$f_{i,j}^{(t+1)} = f_{i,j}^{(t)} - d_{i,j}^{(t)} \quad (4)$$

In case $f_{i,j}^{(t+1)}$ is less than 0, then $f_{i,j}^{(t+1)}$ must be set to 0.

In case $f_{i,j}^{(t+1)}$ is greater than $U - 1$, then $f_{i,j}^{(t+1)}$ must be set to $U - 1$.

A YYPL image is obtained after the above processing (Steps 1 and 2) of T times iteration.

3. Experiments

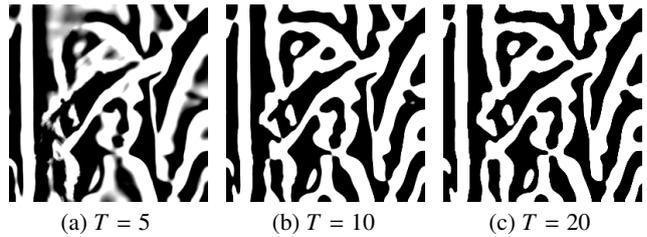
We conducted two experiments: the first experiment was to check the changes in YYPL images generated by changing the values of the parameters in the proposed method, and



Figure 3: Lenna image.



Figure 4: Various photographic images.

Figure 5: YYPL images in the case of the iteration number $T = 5, 10$ and 20 .

the second experiment was to apply the proposed method to various photographic images. The first experiment used Lenna image shown in Figure 3, and the second experiment used six photographic images shown in Figure 4. All photographic images used in the experiments were $256 * 256$ pixels and 256 gradation. Unless otherwise noted in the following experiments, the parameter values T , W , α_1 and α_2 were set to 20, 20, 0.1 and 0.001, respectively.

3.1 Experiment with changing parameters YYPL images by changing the iteration number T were visually confirmed using Lenna image. The iteration number T was set to 5, 10 and 20. The results of the experiment are shown in Figure 5. As the iteration number T increased, YYPL patterns were clear.

YYPL images by changing the window size W were visually confirmed using Lenna image. The window size W was set to 10, 20 and 30. The results of the experiment are shown in Figure 6. As the window size W became larger, the interval between YYPL patterns increases, and Lenna image became more difficult to visually recognize.

YYPL images by changing the parameter α_1 were visually confirmed using Lenna image. The parameter α_1 was

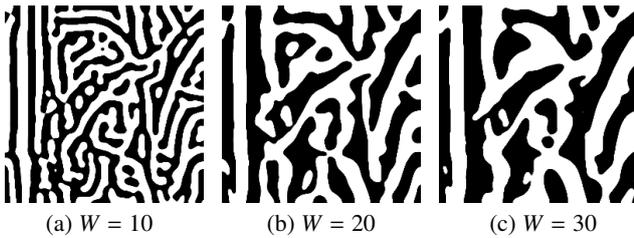


Figure 6: YYPL images in the case of the window size $W = 10, 20$ and 30 .

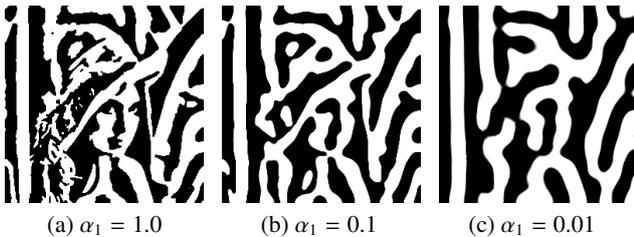


Figure 7: YYPL images in the case of the parameter $\alpha_1 = 1.0, 0.1$ and 0.01 .

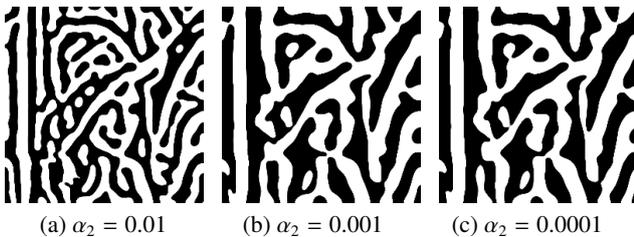


Figure 8: YYPL images in the case of the parameter $\alpha_2 = 0.01, 0.001$ and 0.0001 .

set to 1.0, 0.1 and 0.01. The results of the experiment are shown in Figure 7. As the parameter α_1 became smaller, YYPL patterns became smoother, and Lenna image became more difficult to visually recognize.

YYPL images by changing the parameter α_2 were visually confirmed using Lenna image. The parameter α_2 was set to 0.01, 0.001 and 0.0001. The results of the experiment are shown in Figure 8. As the parameter α_2 became smaller, the interval between YYPL patterns increases, and Lenna image became more difficult to visually recognize.

3.2 Experiment using various photographic images

The proposed method was applied to six photographic images shown in Figure 4. The results of the experiment are shown in Figure 9. All YYPL images could be automatically generated according to the change of the edges and the shading in photographic images. In addition, all YYPL images could express photographic images in black and white areas having smooth curve such as Yin-Yang patterns, and could have few fine textures.

4. Conclusion

We proposed an NPR method for generating YYPL images from photographic images. The proposed method were executed by an iterative calculation using DoG. Through experiments using Lenna image and other photographic images,

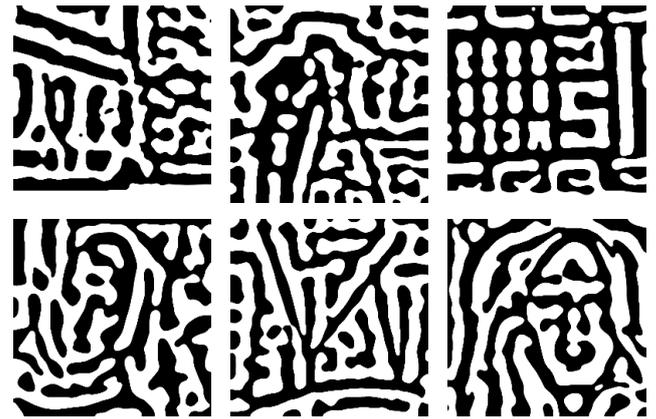


Figure 9: Various YYPL images.

the proposed method could automatically generate YYPL images according to the change of the edges and the shading in photographic images. In addition, the proposed method could express photographic images in black and white areas having smooth curve such as Yin-Yang patterns, and could have few fine textures.

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

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Toru Hiraoka (Member) 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.