ICIC Express Letters
Volume **15**, Number **2**, February **2021**

ICIC International ©2021 ISSN 1881-803X
pp. 143–148

GENERATION OF ARBITRARILY-ORIENTED SPRAY-TILE IMAGES USING SIMILAR WINDOW

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 2020; accepted September 2020

Abstract. *This paper presents a non-photorealistic rendering method for generating arbitrarily-oriented spray-tile images from photographic images. Arbitrarily-oriented spray-tile images are mainly composed on spray-tile patterns in a certain orientation. The proposed method uses a window similar to the window centered on the target pixel in the vicinity of the target pixel. The proposed method can automatically generate arbitrarily-oriented spray-tile images, and can express changes in brightness of photographic images. In addition, the proposed method allows the user to arbitrarily change the orientation of spray-tile patterns. The performance of the proposed method was clarified by conducting experiments on the parameters in the proposed method.*

Keywords: Non-photorealistic rendering, Arbitrarily orientation, Spray tile, Similar window

1. **Introduction.** Various NPR (non-photorealistic rendering) methods have been developed [1, 2, 3, 4, 5, 6, 7]. Images generated by NPR can be appealed to human perception. There are NPRs that imitate the existing drawing techniques such as oil painting and pencil drawing, imitate the style of painting such as Vincent Willem van Gogh and Claude Monet, and express art materials on which pictures are drawn such as canvas and papers. In this paper, we focus on NPR expressing art materials. As NPR expressing art materials, studies have been conducted: the study on generation of canvas textures by sampling and interpolation of pixels of photographic images [8], the study on generation of paper-mosaic images taking account of thickness and texture of papers on the basis of the emboss-filtered images of the overlapped pieces of papers and paper's texture [9], and the study on generation of concrete-wall textures by autocorrelation coefficient and inverse filter [10].

We especially focus on the expressions as drawn on the spray tile shown in Figure 1, and develop an NPR method for automatically generating arbitrarily-oriented spray-tile (AOST) images from photographic images. Spray tile is a tile mainly used for exterior, and has an uneven pattern on the surface. Spray-tile images represent spray-tile patterns on photographic images. AOST images are mainly composed on spray-tile patterns in a certain orientation, which can be arbitrarily changed by users. Our method is implemented by two-step iterative calculation: the first step uses the orientation from the target pixel to the center pixel of the window similar to the window centered on the target pixel, and the second step uses inverse filter [11, 12]. A number of studies have been conducted using similar windows through the whole image [13, 14], although not within the window centered on the target pixel. Liu and Wu [13] applied similar windows to denoising, and Jurio et al. [14] applied similar windows to image inpainting. Our method is easy to process and easy to implement. In addition, our method can express changes in brightness

DOI: 10.24507/icicel.15.02.143

FIGURE 1. Example of spray tile

of photographic images, and can change the size and orientation of spray-tile patterns by changing the parameter values. We conducted experiments with different parameter values to evaluate the effectiveness of our method, and confirmed that our method can change the size and orientation of spray-tile patterns arbitrarily.

This paper is organized as follows: the second section describes our method for generating AOST 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 is executed in two steps: the first step is to process using the window similar to the window centered on the target pixel, and the second step is to process using inverse filter which is calculated by a procedure that restores an image by a process to an original image. AOST images are generated by repeatedly calculating the processes of the first and second steps. That is, AOST patterns are generated by stacking the restoration errors when the image transformed by the first process is restored by the second process. Our method does not perform particularly difficult process, so it is easy to implement. A flow chart of our method is shown in Figure 2.

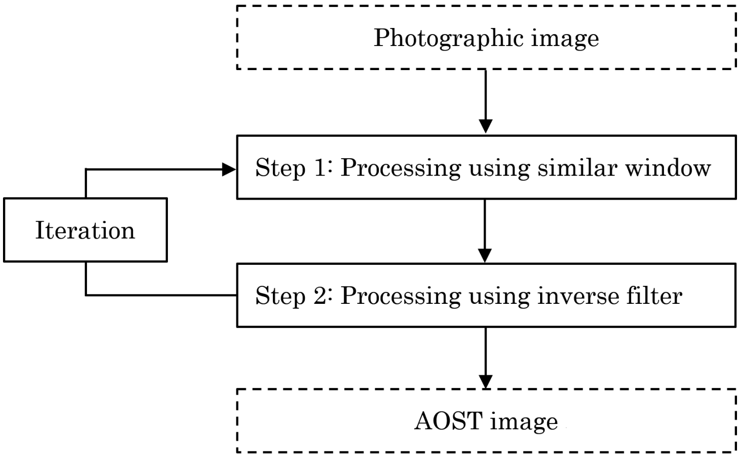


FIGURE 2. Flow chart of our method

Details of the procedure in Figure 2 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 gradation from 0 to $U - 1$. Let the pixel values of the t-th iteration be $f^{(t)}_{i,j}$, where $f^{(0)}_{i,j} = f_{i,j}$.

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

$$d^{(t)}_{i,j,k,l} = \sum_{m=-W}^{W} \sum_{n=-W}^{W} \left| f^{(t-1)}_{i+m,j+n} - f^{(t-1)}_{k+m,l+n} \right| \tag{1}$$

where W is the window size, and m and n are the positions in the window. The larger the values of the window size W, the larger the size of spray-tile patterns. For all pixels contained in the window of size W centered on the target pixel (i, j), the differences $d^{(t)}_{i,j,k,l}$ are calculated, and let the coordinates of the minimum value among the differences $d^{(t)}_{i,j,k,l}$ be $(k_{i,j}, l_{i,j})$. The values $g^{(t)}_{i,j}$ using coordinate values (i, j) and $(k_{i,j}, l_{i,j})$ are calculated as follows.

$$g^{(t)}_{i,j} = \frac{k_{i,j} - i}{\sqrt{(k_{i,j} - i)^2 + (l_{i,j} - j)^2}} \sin(\theta) + \frac{l_{i,j} - j}{\sqrt{(k_{i,j} - i)^2 + (l_{i,j} - j)^2}} \cos(\theta) \quad (2)$$

where θ is an angle [radian], and AOST images in which spray-tile patterns are rotated by θ radian from the horizontal orientation can be generated. The values $h^{(t)}_{i,j}$ using the values $g^{(t)}_{i,j}$ are calculated as follows.

$$h^{(t)}_{i,j} = \frac{U-1}{2} + \frac{U-1}{2} g^{(t)}_{i,j} \quad (3)$$

Step 2: The pixel values $f^{(t)}_{i,j}$ are computed using inverse filter as follows.

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

where in case $f^{(t)}_{i,j}$ is smaller than 0, $f^{(t)}_{i,j}$ must be set to 0. In case $f^{(t)}_{i,j}$ is greater than $U - 1$, $f^{(t)}_{i,j}$ must be set to $U - 1$.

The processes of Step 1 and Step 2 are repeated T times. An image composed of the pixel values $f^{(T)}_{i,j}$ is the AOST image.

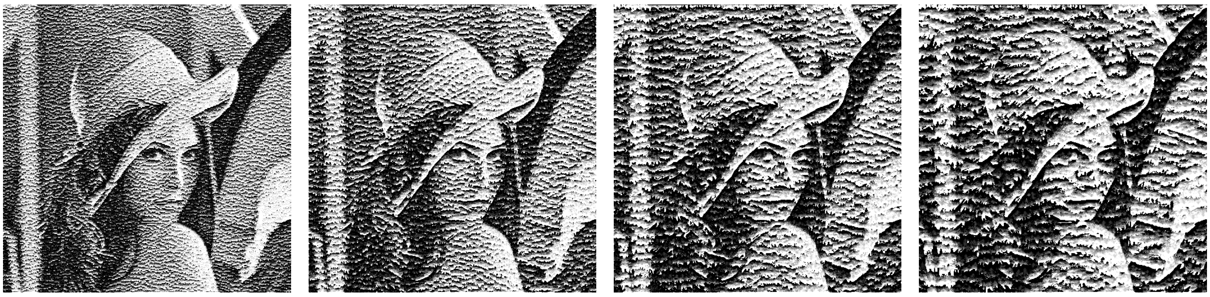
3. **Experiments.** We mainly conducted two experiments: the first experiment with changing the parameter values in our method was conducted using Lenna image shown in Figure 3, and the second experiment was conducted to visually verify that AOST images can be generated using four photographic images shown in Figure 4. All photographic images used in the experiments were $512 * 512$ pixels and 256 gradation. Since AOST

Figure 3. Lenna image

Figure 4. Various photographic images

images converge and stop changing, the value of the iteration number T was set to 10 in all experiments.

3.1. **Experiments with different parameter values.** We visually confirmed AOST 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 θ to 0.0. The results of the experiment with changing the value of W are shown in Figure 5. As the value of W was larger, spray-tile patterns became larger and it became difficult to visually recognize Lenna image. The value of W may be set according to the application of the user.



(a) $W = 1$ (b) $W = 2$ (c) $W = 3$ (d) $W = 4$

FIGURE 5. AOST images generated by changing the value of the window size W

We visually confirmed AOST images changed the value of the angle θ using Lenna image. We set the value of θ to $\pi/6$, $\pi/3$, $\pi/2$ and $2\pi/3$, and set the value of W to 2. The results of the experiment with changing the value of θ are shown in Figure 6. Depending on the value of θ, the orientation of spray-tile patterns is changing. The value of θ may be set according to the application of the user.

(a) $\theta = \pi/6$ (b) $\theta = \pi/3$ (c) $\theta = \pi/2$ (d) $\theta = 2\pi/3$

FIGURE 6. AOST images generated by changing the value of the angle θ

3.2. **Experiments using various photographic images.** We applied our method to four photographic images shown in Figure 4. Since spray-tile patterns were visually recognized well in the previous experiments, we set the values of the parameters W and θ to 2 and 0.0, respectively. The results of the experiment are shown in Figure 7. In all AOST images, spray-tile patterns could be automatically generated, and could be expressed changes in brightness of photographic images. However, it was difficult to generate AOST patterns in the white areas such as 'upper center and bottom of the third image' and 'lighthouse and roof in the fourth image' in Figure 7. To generate AOST patterns in the white areas as well, it is necessary to add noise, such as Gaussian noise, to the white areas of photographic images. AOST images generated by our method had a completely different texture from NPR images generated by the conventional methods [8, 9, 10], and

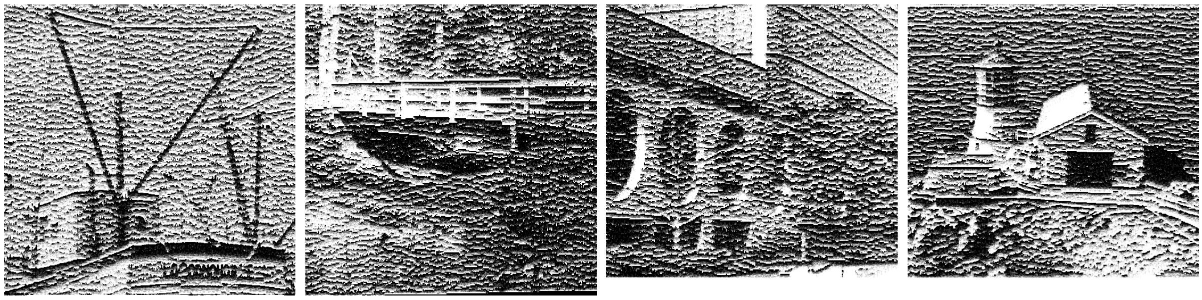


Figure 7. AOST images

our method had the advantage of being able to control the orientation of AOST patterns compared to the conventional methods.

4. **Conclusions.** We developed an NPR method for generating AOST images from gray-scale photographic images. Our method was executed by an iterative calculation using the orientation to the similar window and inverse filter. The effectiveness of our method was visually verified through experiments using Lenna image and various images. The experimental results showed that our method can automatically generate spray-tile patterns, can express changes in brightness of photographic images, and can arbitrarily change the size and the orientation of spray-tile patterns by changing the parameter values. However, it was difficult to generate AOST patterns in the white areas of photographic images.

A subject for future study is to be able to generate AOST patterns by adding Gaussian noise or the like to the white areas of photographic images. Another task is to expand our method for application to color photographic images, videos and three-dimensional models.

Acknowledgments. This work was supported by JSPS KAKENHI Grant Number JP19-K12664.

REFERENCES

[1] P. Haeberli, Paint by numbers: Abstract image representations, *ACM SIGGRAPH Computer Graphics*, vol.24, no.4, pp.207-214, 1990.

[2] 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.

[3] J. Daniel, S. Erik, Y. Anders and R. Timo, A survey of volumetric illumination techniques for interactive volume rendering, *Computer Graphics Forum*, vol.33, no.1, pp.27-51, 2014.

[4] B. Dalstein, R. Ronfard and M. V. D. Panne, Vector graphics animation with time-varying topology, *ACM Transactions on Graphics*, vol.34, no.4, article no.145, 2015.

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

[6] K. Lawonn, I. Viola, B. Preim and T. Isenberg, A survey of surface-based illustrative rendering for visualization, *Computer Graphics Forum*, vol.37, no.6, pp.205-234, 2018.

[7] T. Hiraoka, Generation of pop art-like images using binomial distribution, *ICIC Express Letters*, vol.14, no.3, pp.227-233, 2020.

[8] K. Inoue and K. Urahama, Generating canvas textures by sampling and interpolation of pixels, *The Journal of the Institute of Image Information and Television Engineers*, vol.59, no.10, pp.1475-1477, 2005.

[9] D. Makino, K. Inoue, K. Hara and K. Urahama, Generating paper mosaic images taking into account thickness and texture of paper, *The Journal of the Institute of Image Information and Television Engineers*, vol.60, no.12, pp.2038-2041, 2006.

[10] T. Hiraoka, T. Katayama and K. Urahama, Generation of concrete-wall-like images by autocorrelation coefficient and inverse filtering, *ICIC Express Letters*, vol.13, no.2, pp.127-132, 2019.

[11] J. M. Ortega and W. C. Rheinboldt, Iterative solutions of nonlinear equations in several variables, *Society for Industrial and Applied Mathematics*, 1987.

[12] Z. Yu and K. Urahama, Iterative method for inverse nonlinear image processing, *IEICE Transactions on Fundamentals*, vol.E97-A, no.2, pp.719-721, 2014.

[13] W. Liu and S. Wu, Superpixels-based non-local means image denoising, *2016 IEEE the 11th Conference on Industrial Electronics and Applications*, 2016.

[14] A. Jurio, D. Paternain, M. Pagola, C. Marco-Detchart and H. Bustince, Two-step algorithm for image inpainting, *Proc. of the Conference of the European Society for Fuzzy Logic and Technology*, pp.302-313, 2017.