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GENERATING STRIPE-PATCHWORK-LIKE HALFTONING BY *k*-MEANS CLUSTERING AND INVERSE FILTER

Toru Hiraoka[1] and Hirohumi Nonaka[2]

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

[2]Department of Information and Management Systems Engineering
Nagaoka University of Technology
1603-1, Kamitomioka-cho, Nagaoka, Nigata-ken 940-2188, Japan
nonaka@kjs.nagaokaut.ac.jp

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Abstract. *Non-photorealistic screening, image-based dithering, and Voronoi division method were proposed as a non-photorealistic halftoning method. In this paper, we propose a non-photorealistic halftoning method for generating stripe-patchwork-like halftoning (SPLH) from photographic images by using k-means clustering and inverse filter. In order to evaluate the performance of our method, we conduct experiments by using Lena gray-scale image and other photographic images. In this experiment, we investigate the visual effects of SPLH when changing the values of the parameters in our method. As a result, we confirmed that our method can generate SPLH, and showed the variations that could be generated in SPLH by changing the parameters in our method.*

Keywords: Non-photorealistic rendering, Halftoning, Stripe, Patchwork, SPLH, k-means clustering, Inverse filter

1. Introduction.

Non-photorealistic screening [1], image-based dithering [2], and Voronoi division method [3] were proposed as a non-photorealistic halftoning method. Halftoning is a technique that expresses gray scale by using only black and white. Non-photorealistic rendering is a technique of computer graphics that converts a photographic image or 3-dimensional model into an art form such as pointillism [4], labyrinthine image [5] and cartoon [6]. These images are frequently seen in our daily lives such as television programming, magazines, and web pages. Thus, various non-photorealistic rendering techniques are required.

In this paper, we focus on a non-photorealistic halftoning to develop a variety of non-photorealistic rendering, and propose a non-photorealistic halftoning method for generating stripe-patchwork-like halftoning (SPLH) from photographic images by using k-means clustering and inverse filter [7]. Stripe patchwork (Figure 1) is a technique for sewing together pieces of stripe fabric into a larger design, and provides design variations. SPLH has characteristics that the width and the local direction of stripe-patchwork-like patterns can be automatically generated in accordance with the luminance and the shading of photographic images. Our method is different from the conventional non-photorealistic halftoning methods [1, 2, 3], and generates different halftoning patterns from the conventional methods. While our method can generate stripe-patchwork-like patterns from photographic images, the conventional methods cannot generate it. So as we know, non-photorealistic halftoning methods for generating SPLH have not been presented until now.

In order to evaluate the performance of our method, we conduct experiments by using Lena gray-scale image (Figure 2). In this experiment, we investigate the visual effects of

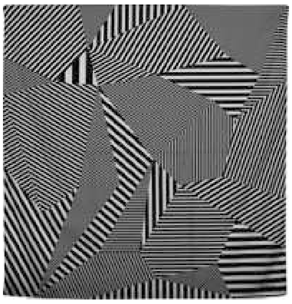


Figure 1. Example of stripe patchwork

Figure 2. Lena gray-scale image

SPLH when changing the values of the parameters in our method. These results can be used as an index for generating SPLH from various photographic images. As an additional experiment, we apply our method to several photographic gray-scale images, and confirm the visual effects of SPLH.

The rest of this paper is organized as follows. Section 2 describes our method for generating SPLH by using k-means clustering and inverse filter. Section 3 shows experimental results, and reveals how to change SPLH when changing the values of the parameters in our method. Finally, Section 4 concludes this paper.

2. **Our Method.**

Our method generates SPLH by using k-means clustering and inverse filter. k-means clustering is a method of vector quantization that is classified into k number of clusters given by cluster average. The procedure of k-means clustering follows the way to classify a given dataset through a certain number of clusters (k clusters) fixed a priori. The first step is to set initial k cluster centers. The second step is to take each point belonging to the given dataset and associate it to the nearest cluster center. The third step is to re-calculate k new centroids as barycenter of the clusters resulting from the second step. The second and third steps are repeated until the cluster centers do not move any more. Inverse filter is calculated by using a procedure that restores an image converted by a processing to an original image. The procedure of inverse filter follows the iterative calculations of adding the difference between the pixel values before and after converting the image by the processing to the first converted image.

Let 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 256 gradation from 0 to 255. Also, let us prepare $f'_{i,j}$ having the same value as the pixel values $f_{i,j}$. Let the vector that is arranged the pixel values of pixels included within window size $W * W$ centered on the pixel (i, j) be $V_{i,j}$. Let the elements of the vector $V_{i,j}$ be $(v_{i,j,1}, v_{i,j,2}, \dots, v_{i,j,w}, \dots, v_{i,j,W^2})$.

The processing procedure of our method is as follows.

1) Vectors $V_{i,j}$ are classified into K classes by using k-means method. Let the vectors of cluster centers of each class be $V_k = (v_{k,1}, v_{k,2}, \dots, v_{k,W^2})$ $(k = 1, 2, \dots, K)$.

2) Each class is sorted in ascending order of the average of the elements of the cluster center vector V_k. Let the sorted class be $S_k = (s_{k,1}, s_{k,2}, \ldots, s_{k,W^2})$ $(k = 1, 2, \ldots, K)$.
3) The vector $V_{i,j}$ is classified into S_k.
4) If the pixel value $f_{i,j}$ of the photographic image is classified into the kth class, let its pixel value be $g_{i,j} = 255(k-1)/(K-1)$.
5) Using inverse filter, the pixel value $f_{i,j}$ of the photographic image is updated by $f_{i,j} = f_{i,j} - g_{i,j} + f'_{i,j}$, where $f_{i,j}$ set to 0 if their values are less than 0, and set to 255 if their values are greater than 255.
6) Repeat T times from processing 3 to 5.

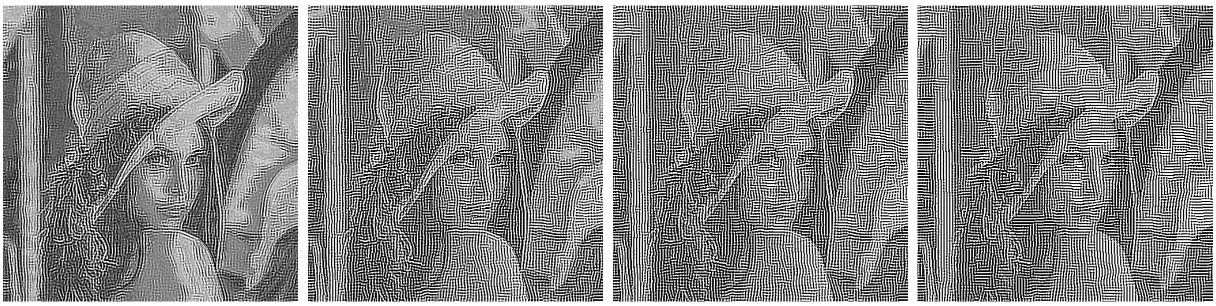
Finally, SPLH is obtained after the above processing.

3. **Experiments.** First, we applied our method to the gray-scale image of $512 * 512$ size and 256 tone of Lena, and investigated the variation in SPLH when changing iteration number T to 10, 20, 40, 160. In this experiment, the value of W was set to 7 and the value of K was set to 15. Figure 3 is the result of it. Observing Figure 3, as the value of T increases, the stripe-patchwork-like patterns become clearer.

Next, we apply our method to Lena gray-scale image, and investigated the variation in SPLH when changing window size W to 3, 5, 7, 9. In this experiment, the value of T was set to 160 and the value of K was set to 15. Figure 4 is the result of it. Observing Figure 4, as the value of W increases, the spacing of the stripes becomes wider.

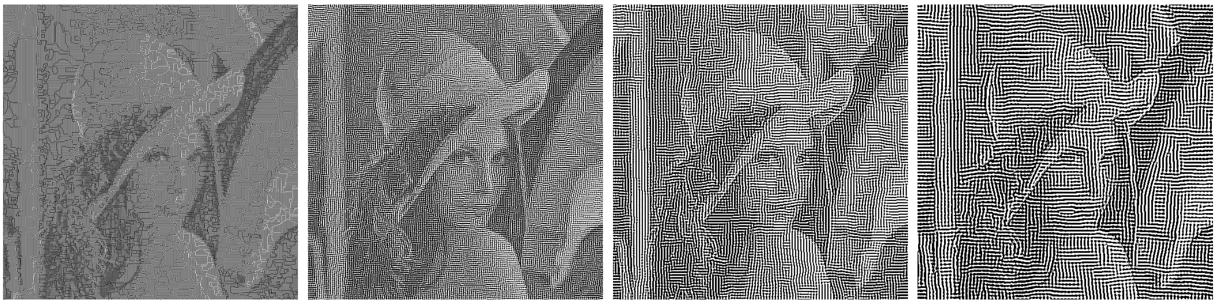
Next, we apply our method to Lena gray-scale image, and investigated the variation in SPLH when changing cluster number K to 5, 10, 15, 20. In this experiment, the value of T was set to 160 and the value of W was set to 7. Figure 5 is the result of it. Observing Figure 5, as the value of K increases, the region of the patchwork becomes larger and the shading decreases in the right side of the shoulder and hat in Figure 5(a).

By conducting the above experiments with different values of the parameters in our method, the following was revealed.



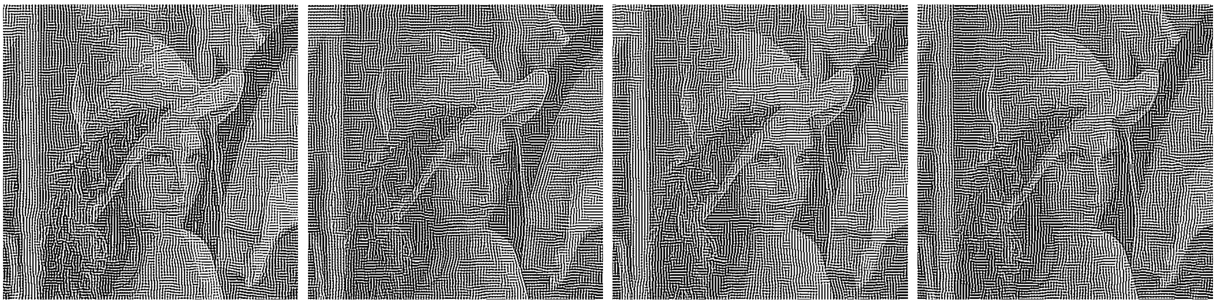
(a) $T = 10$ (b) $T = 20$ (c) $T = 40$ (d) $T = 160$

FIGURE 3. Variation in SPLH with iteration number T



(a) $W = 3$ (b) $T = 5$ (c) $W = 7$ (d) $W = 9$

FIGURE 4. Variation in SPLH with window size W

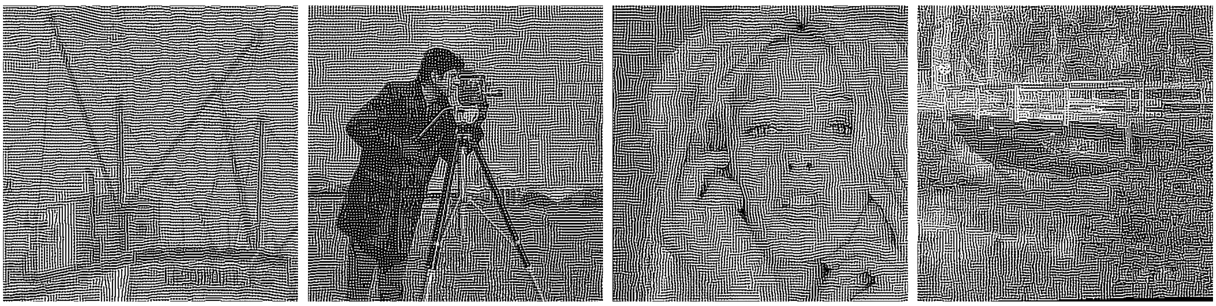


(a) $K = 5$ (b) $K = 10$ (c) $K = 15$ (d) $K = 20$

FIGURE 5. Variation in SPLH with cluster number K

(a) Boat (b) Cameraman (c) Woman (d) Bridge

FIGURE 6. Photographic gray-scale images



(a) Boat (b) Cameraman (c) Woman (d) Bridge

FIGURE 7. SPLH

- As the value of T increases, the stripe-patchwork-like patterns become clearer.
- As the value of W increases, the spacing of the stripes becomes wider.
- As the value of K increases, the region of the patchwork becomes larger and the shading decreases.

Finally, we applied our method to four photographic gray-scale images of $512 * 512$ size and 256 tone (Figure 6). In this experiment, the values of T, W and K were set to 160, 7 and 15, respectively. Figure 7 is the result of it. Observing Figure 7, in all cases, SPLH was the halftoning image generated the stripe-patchwork-like patterns, and had characteristics that the width and the local direction of stripe-patchwork-like patterns can be automatically generated in accordance with the luminance and the shading of photographic images.

4. **Conclusions.** We proposed a non-photorealistic halftoning method for generating SPLH from photographic images by using k-means method and inverse filter. In order to evaluate the performance of our method, we conducted experiments by using Lena gray-scale image. In this experiment, we investigated the visual effects of SPLH when

changing parameters in our method. We also applied our method to several photographic gray-scale images, and confirmed the visual effects of SPLH. Experimental results showed that it is possible to generate the stripe-patchwork-like patterns by using our method. And we also revealed how to change stripe-patchwork-like patterns when changing the values of the parameters in our method. In future work, we will try to apply our method to color photographic images and motion images.

REFERENCES

[1] V. Ostromoukhov and R. D. Hersch, Artistic screening, *Proc. of ACM SIGGRAPH*, pp.219-228, 1995.

[2] O. Veryovka and J. W. Buchanan, Halftoning with image-based dither screens, *Proc. of Graphics Interface*, pp.167-174, 1999.

[3] Z. Yu and K. Urahama, Non-photorealistic halftoning by anisotopic centroidal voronoi tessellation, *IEICE Trans. Information and Systems*, vol.95, no.4, pp.1061-1064, 2012.

[4] J. Sugita and T. Takahashi, A method to generate hybrid pointillistic images, *Proc. of ACM SIGGRAPH Asia 2015 Posters*, 2015.

[5] H. Zhao, F. Gu, Q. X. Huang, J. Garcia, Y. Chen, C. Tu, B. Benes, H. Zhang, D. Cohen-Or and B. Chen, Connected fermat spirals for layered fabrication, *Proc. of ACM SIGGRAPH*, vol.35, no.4, p.100, 2016.

[6] Y. Zhang, W. Dong, O. Deussen, F. Huang, K. Li and B. G. Hu, Data-driven face cartoon stylization, *Proc. of ACM SIGGRAPH Asia 2014 Technical Briefs*, no.14, 2014.

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