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GENERATION OF STRIPE-PATCHWORK IMAGES BY ENTROPY AND INVERSE FILTER

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Abstract. *We proposed a non-photorealistic rendering method for generating stripe-patchwork images from photographic images. The proposed method generates stripe-patchwork images by an iterative process using entropy and inverse filter. The proposed method has two characteristics that stripe-patchwork patterns can be automatically generated in accordance with the shading and the edge of photographic images, and the types and width of stripe-patchwork patterns can be adjusted by varying the value of the parameter in the proposed method. In order to verify the performance of the proposed method, we conduct experiments by using Lena gray-scale image and other photographic images. In this experiment, we investigate the visual effects of stripe-patchwork images when changing parameters in the proposed method.*
Keywords: Non-photorealistic rendering, Stripe patchwork, Entropy, Inverse filter

1. **Introduction.** For rendering in computer graphics, there are photorealistic and non-photorealistic renderings. Photorealistic and non-photorealistic renderings generate photorealistic and non-photorealistic images, respectively. In non-photorealistic rendering, many researches have been conducted to generate non-photorealistic images such as labyrinthine image [1, 2, 3, 4], pointillistic image [5, 6, 7, 8, 9] and striped image [10, 11, 12, 13] from photographic images. Such non-photorealistic rendering has gained attention in terms of amusement and entertainment that provide a visually interesting effect in recent years. Various non-photorealistic rendering methods have been proposed, but non-photorealistic rendering method for generating stripe-patchwork images is only one [15] as far as authors investigate.

This paper proposes a non-photorealistic rendering method for generating stripe-patchwork images from photographic images. Stripe patchwork is a technique that makes variable design by sewing cloth pieces of various stripe patterns in various orientations as shown in Figure 1. Stripe-patchwork images are non-photorealistic images that imitate stripe patchwork and locally change stripe-patchwork patterns in accordance with the shading and the edge of photographic images. The proposed method generates stripe-patchwork images by an iterative process using inverse filter [14] and entropy. The proposed method has two characteristics that stripe-patchwork patterns can be automatically generated in accordance with the shading and the edge of photographic images, and the types and width of stripe-patchwork patterns can be adjusted by varying the value of the parameter in the proposed method.

In order to verify the performance of the proposed method, the visual effects of stripe-patchwork images are investigated by using Lena gray-scale image shown in Figure 2

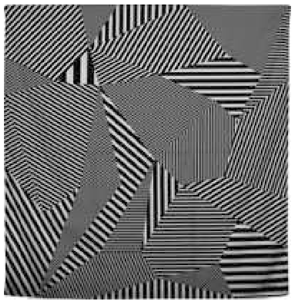


Figure 1. Example of stripe patchwork

Figure 2. Lena gray-scale image

when changing parameters of the proposed method. These results can be used as an index for generating stripe-patchwork images from various photographic images. The proposed method is also applied to a variety of photographic images in addition to Lena gray-scale image. A non-photorealistic rendering method for generating stripe-patchwork images similar to the proposed method has been proposed [15] (conventional method). Therefore, the visual effects of stripe-patchwork images by the proposed method and the conventional method are compared by subjective evaluation using a questionnaire survey.

The rest of this paper is organized as follows. Section 2 describes the proposed method for generating stripe-patchwork images by the iterative process using entropy and inverse filter. Section 3 shows experimental results by using Lena gray-scale image and other photographic images. Finally, Section 4 concludes this paper.

2. **Proposed Method.** The proposed method generates stripe-patchwork images by the iterative process using entropy and inverse filter. Specifically, photographic images are converted by using entropy with the appearance frequency of the pixel value in the window centered on a certain pixel, and then the converted images are restored to photographic images by using inverse filter. By repeating these processes, stripe-patchwork images are generated. During the iterative process, the pixel values in the conventional method have stepwise values due to clustering, but the pixel values in the proposed method have continuous values by using entropy. Therefore, the appearance of stripe-patchwork images of the proposed method is improved over the conventional method. The processing procedure of the proposed method is as follows.

Let input pixel value on coordinate (i, j) of a gray-scale photographic image be $o_{i,j}$. The pixel value $o_{i,j}$ has value of 256 gradation from 0 to 255. In the following experiments, stripe-patchwork patterns were difficult to occur when the pixel value $o_{i,j}$ was small and large, so the range of the pixel value $o_{i,j}$ is converted from a and b as follows:

$$f_{i,j} = a + \frac{o_{i,j}(b-a)}{255} \tag{1}$$

where $f_{i,j}$ is the converted pixel value, and a and b are positive constants that are less than or equal to 255 ($a < b$). In the following experiments, by the trial and error of experiments, the values of a and b are set to 20 and 215, respectively. Since there was a tendency for stripe-patchwork patterns to be less likely to occur in a large pixel value than in a small pixel value, the range of the large pixel value is narrowed compared with the range of the small pixel value.

Let $round(f_{i,j}M/256)$ be $g_{i,j}$, where M is positive constant ($M \leq 256$), $round()$ is a function that truncates decimal point, and $g_{i,j}$ allocates the pixel value $f_{i,j}$ to M sections of $256/M$ interval. The number of values from 0 to $M-1$ is counted for $g_{i,j}$ in the window of $\pm W$ centered on the certain coordinate (i,j), and let the counted value be $h_{i,j,m}$ ($m = 0, 1, \ldots, M-1$). An entropy $E_{i,j}$ on coordinate (i,j) is calculated as follows:

$$E_{i,j} = -\sum_{m=0}^{M-1} \frac{h_{i,j,m}}{(2W+1)^2} \ln \frac{h_{i,j,m}}{(2W+1)^2} \tag{2}$$

A value $EN_{i,j}$ that normalized $E_{i,j}$ from 0 to 255 is calculated as follows:

$$EN_{i,j} = 255 \frac{E_{i,j} - E_{\min,i,j}}{E_{\max,i,j} - E_{\min,i,j}} \tag{3}$$

where $E_{\min,i,j}$ and $E_{\max,i,j}$ are the minimum and maximum values of $E_{i,j}$, respectively.

The pixel value $f_{i,j}$ is updated by using the normalized entropy $EN_{i,j}$ and inverse filter as follows:

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

where t is iteration number. The initial value $f_{i,j}^{(0)}$ is set to $f_{i,j}$, and $f_{i,j}^{(1)}, f_{i,j}^{(2)}, \ldots, f_{i,j}^{(t)}$ are calculated sequentially in Equation (4). The pixel value $f_{i,j}^{(t)}$ is 0 if $f_{i,j}^{(t)}$ is less than 0, and $f_{i,j}^{(t)}$ is 255 if $f_{i,j}^{(t)}$ is greater than 255.

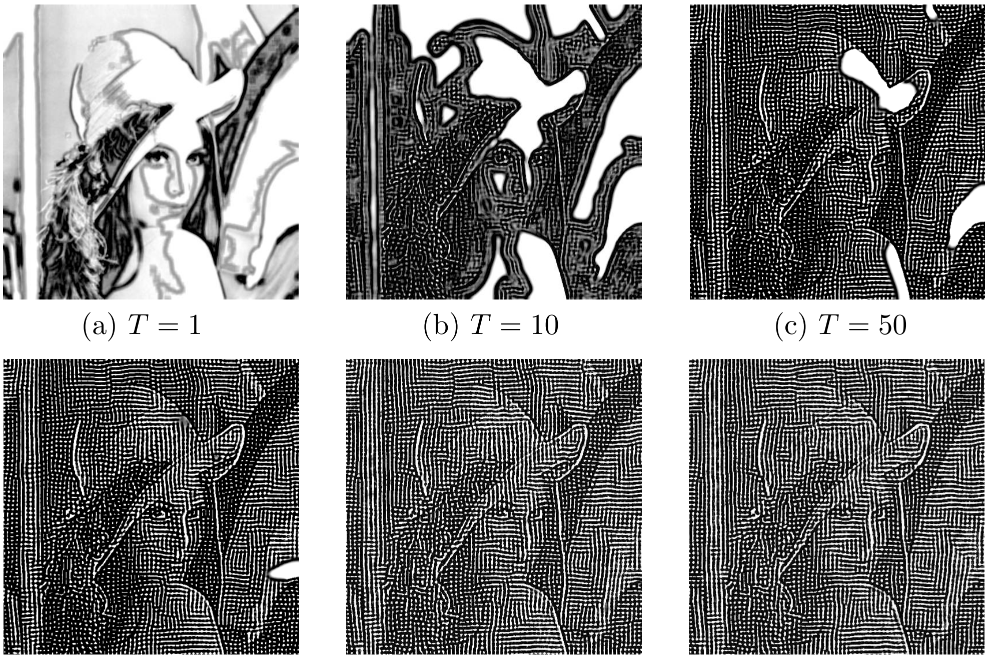
The image after calculating T times in Equation (4) is the stripe-patchwork image by the proposed method.

3. **Experiments.** First, the proposed method was applied to Lena gray-scale image of $512*512$ pixel size and 256 tone, and investigated the variation in stripe-patchwork images when changing iteration number T to 1, 10, 50, 100, 200 and 400. In this experiment, the values of M and W were set to 4 and 5, respectively. This result was shown in Figure 3. Figure 3 showed that stripe-patchwork patterns became clearer as the value of T increased. In order to express stripe-patchwork patterns on entire photographic images, the value of T should be set to 200 or more in image of $512 * 512$ pixel size.

Next, the proposed method was applied to Lena gray-scale image, and investigated the variation in stripe-patchwork images when changing section number M to 2, 3, 4 and 5. In this experiment, the values of T and W were set to 400 and 5, respectively. This result was shown in Figure 4. Figure 4 showed that the types of stripe-patchwork patterns increased as the value of M decreased. In order to express stripe-patchwork patterns clearly, the value of M should be set around 4.

Next, the proposed method was applied to Lena gray-scale image, and investigated the variation in stripe-patchwork images when changing window size W to 3, 5, 7, 9. In this experiment, the values of T and M were set to 400 and 4, respectively. This result was shown in Figure 5. Figure 5 showed that the space of stripe-patchwork patterns became wider as the value of W increased. In order to make it easier to recognize stripe-patchwork patterns and original photographic images, the value of W is desirable to set around 5.

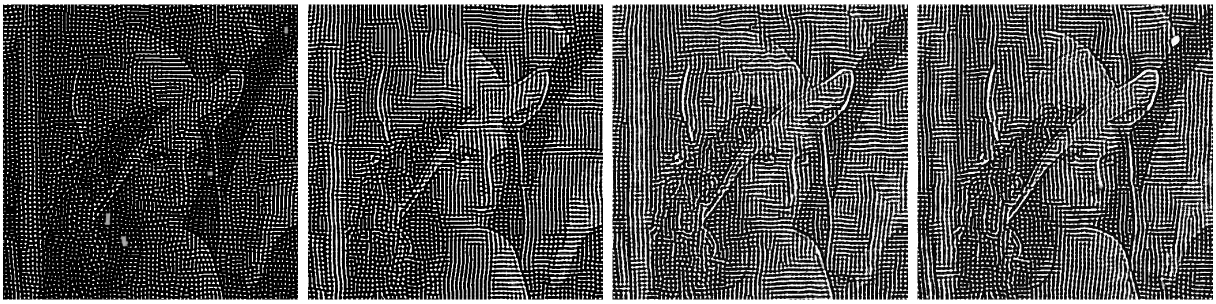
Next, the proposed method was applied to four photographic gray-scale images of $512*512$ pixel size and 256 tone shown in Figure 6. In this experiment, the values of T, M and W were set to 400, 4 and 5, respectively. However, in case of Figure 6(a), since



(a) $T = 1$ (b) $T = 10$ (c) $T = 50$

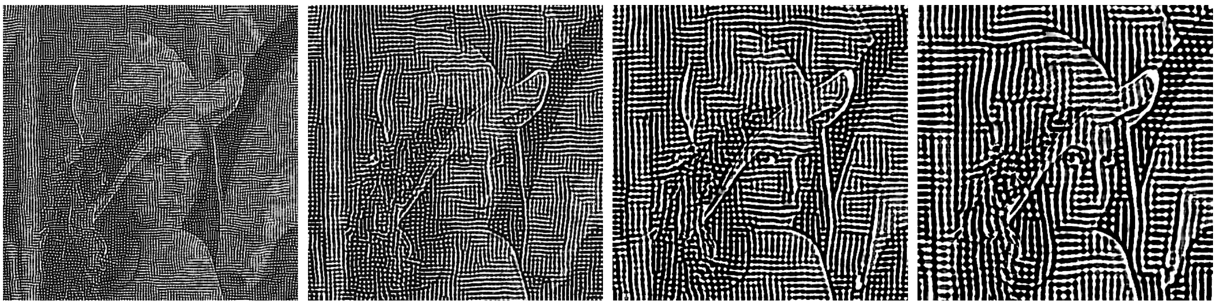
(d) $T = 100$ (e) $T = 200$ (f) $T = 400$

FIGURE 3. Variation in stripe-patchwork images with iteration number T



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

FIGURE 4. Variation in stripe-patchwork images with section number M



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

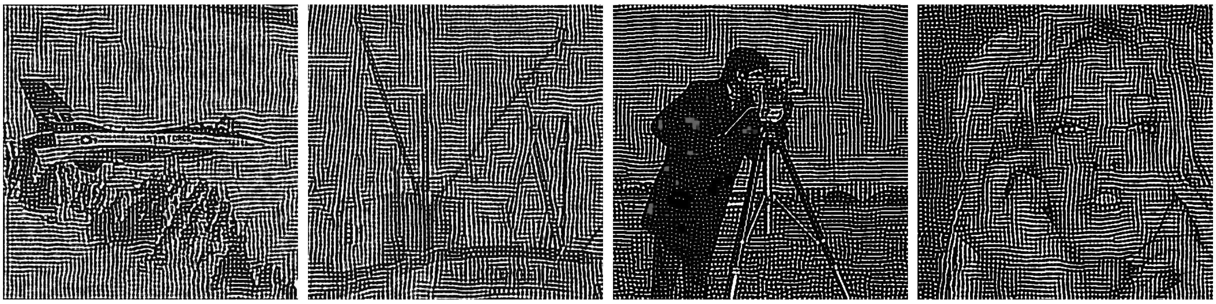
FIGURE 5. Variation in stripe-patchwork images with window size W

stripe-patchwork image did not converge at $T = 400$, T was set to 1000. This result was shown in Figure 7. Figure 7 showed that stripe-patchwork patterns could be automatically generated in accordance with the shading and the edge of all photographic images.

Finally, the visual effects of stripe-patchwork images by the proposed method and the conventional method [15] were compared by subjective evaluation using the questionnaire survey. In the questionnaire survey, Figure 3(f) and Figure 8 were presented to subjects

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

Figure 6. Photographic gray-scale images



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

Figure 7. Stripe-patchwork images

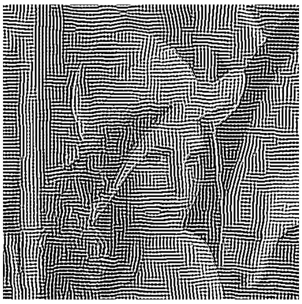


Figure 8. Stripe-patchwork image of the conventional method

as stripe-patchwork images of the proposed method and the conventional method, respectively, and then subjects selected one of two stripe-patchwork images that was similar to stripe patchwork of Figure 1. The number of subjects was 10 (8 men, 2 women) from 24 to 58 years old. As a result of the questionnaire survey, the numbers of subjects who selected stripe-patchwork image of the proposed method and the conventional method were 10 and 0, respectively. Therefore, this result showed that the proposed method could generate stripe-patchwork images that were similar to stripe patchwork compared with the conventional method.

4. **Conclusions.** This paper proposed a non-photorealistic rendering method for generating stripe-patchwork images by an iterative process using entropy and inverse filter from photographic images. In order to verify the performance of the proposed method, the visual effects of stripe-patchwork images were investigated by using Lena gray-scale image when changing parameters of the proposed method. The proposed method was also applied to a variety of photographic images in addition to Lena image. As a result of the experiments, the proposed method showed that stripe-patchwork patterns could be

automatically generated in accordance with the shading and the edge of photographic images, and the types and width of stripe-patchwork patterns could be adjusted by varying the value of the parameter in the proposed method.

Further studies are needed to apply the proposed method to color and moving images. Another future challenge is to enable the automatic setting of optimal parameter values depending on photographic images.

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