ICIC Express Letters
Volume **15**, Number **3**, March **2021**

ICIC International ©2021 ISSN 1881-803X
pp. **235–240**

A COMPOSITION METHOD OF TWO STRIPE-PATCHWORK IMAGES

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Received July 2020; accepted September 2020

Abstract. *Non-photorealistic rendering (NPR) methods have been proposed for generating stripe-patchwork (SP) images from photographic images. SP images imitate stripe-patchwork, and SP patterns locally change in accordance with shading and edges of photographic images. We consider that if two SP images are combined, composite SP (CSP) images having a visually interesting effect are obtained. At this time, CSP patterns need to be generated by smoothly connecting two SP patterns. Therefore, we in this paper develop a method to connect two SP patterns by devising the averages of the pixel values of two images in the iterative processing using smoothing filter and inverse filter. We conducted experiments applying our method to various photographic images, and visually confirmed that CSP images in which two SP patterns are smoothly synthesized are generated.*
Keywords: Non-photorealistic rendering, Stripe-patchwork, Composition, Smoothing filter

1. **Introduction.** Many researches on NPR that transforms images, videos and 3D data into non-realistic images such as oil paintings and watercolors have been conducted [1, 2]. NPR is provided as one of the applications embedded in smartphones and personal computers, and is required from the fields of entertainment and amusement with visually interesting effects. Image processing techniques [3, 4] are used in such NPR utilization. One type of NPR that uses image processing techniques is to generate SP images from photographic images [5, 6, 7, 8]. In [5], a method by an iterative processing using inverse filter [9, 10] and entropy was proposed, and SP patterns could be automatically generated in accordance with shading and edges of photographic images. In [6], a method by an iterative processing using smoothing filter according to the distance from the target pixel and inverse filter was proposed, and the brightness of edges of photographic images could be preserved more than the conventional method [5]. In [7], the conventional method [6] was improved by using lookup table and sampling, and the processing could be performed at a higher speed than the conventional method [6]. In [8], the conventional method [6] was improved by selecting the pixels in the window used in the smoothing process, and the direction of SP patterns could be changed.

We in this paper develop a method to synthesize two SP images for the purpose of improving the visual effect of SP images. Our method is based on the concept of the conventional method [6], takes two photographic images as input, and is executed by an iterative processing using smoothing filter and inverse filter with the averages of the

DOI: 10.24507/icicel.15.03.235

pixel values of two images. The features of our method are that SP patterns of two SP images can be connected smoothly, and two SP images can be visually recognized from one CSP image. To verify the effectiveness of our method, experiments were conducted using various photographic images, and were conducted to visually examine changes in CSP images generated by changing the parameter values of our method. The experimental results showed that the features of our method can be realized.

The rest of this paper is organized as follows. Section 2 describes our method for generating CSP images. Section 3 shows experimental results, and reveals the effectiveness of our method. Finally, Section 4 concludes this paper.

2. **Our Method.** Our method is executed by the iterative processing with two steps, and generates two CSP images (CSP image A and CSP image B) from two photographic images (photographic image A and photographic image B). The first step uses smoothing filter, and the second process uses inverse filter. Photographic images are smoothed by smoothing filter, and the smoothed images are restored to photographic images by inverse filter. By repeating the processing, restoration errors are accumulated and CSP images are generated. A flow chart of our method is shown in Figure 1.

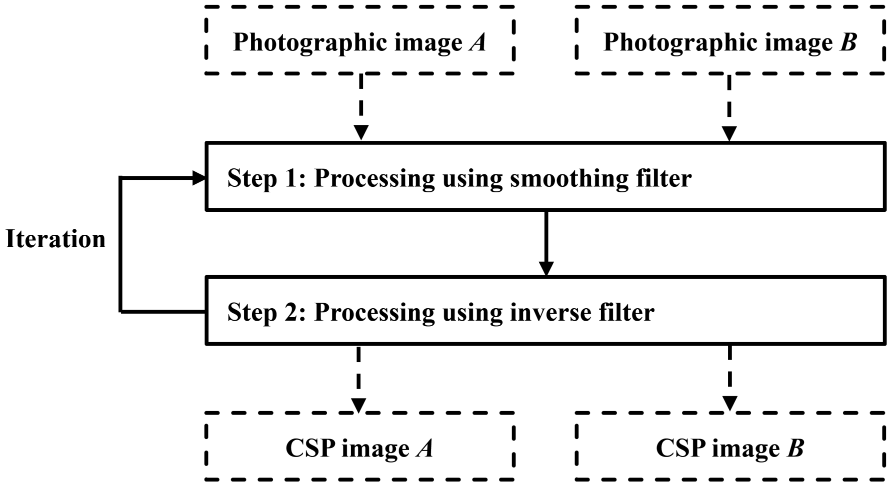


Figure 1. Flow chart of our method

The detailed procedure in Figure 1 is shown as follows.

Step 0: The pixel values on coordinates (i, j) of two photographic images A and B of the same size are defined as $f_{A,i,j}$ and $f_{B,i,j}$ $(i = 1, 2, \ldots, I;\ j = 1, 2, \ldots, J)$. The pixel values $f^{(t)}_{A,i,j}$ and $f^{(t)}_{B,i,j}$ of the images at the t-th iteration number have value of M gradation from 0 to $M-1$, where $f^{(0)}_{A,i,j} = f_{A,i,j}$ and $f^{(0)}_{B,i,j} = f_{B,i,j}$.

Step 1: The pixel values $f^{(t-1)}_{A,i,j}$ and $f^{(t-1)}_{B,i,j}$ are respectively smoothed to the pixel values $SM\left(f^{(t-1)}_{A,i,j}\right)$ and $SM\left(f^{(t-1)}_{B,i,j}\right)$ as

$$SM\left(f^{(t-1)}_{A,i,j}\right) = \frac{\sum_{k=-W}^{W}\sum_{l=-W}^{W} f^{(t-1)}_{A,i+k,j+l}}{(2W+1)^2} \tag{1}$$

$$SM\left(f^{(t-1)}_{B,i,j}\right) = \frac{\sum_{k=-W}^{W}\sum_{l=-W}^{W} f^{(t-1)}_{B,i+k,j+l}}{(2W+1)^2} \tag{2}$$

where W is the window size, and k and l are the positions in the window.

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

$$f^{(t)}_{A,i,j} = g^{(t-1)}_{i,j} - SM\left(f^{(t-1)}_{A,i,j}\right) + f_{A,i,j} \tag{3}$$

$$f_{B,i,j}^{(t)} = g_{i,j}^{(t-1)} - SM\left(f_{B,i,j}^{(t-1)}\right) + f_{B,i,j} \tag{4}$$

$$g_{i,j}^{(t-1)} = \frac{f_{A,i,j}^{(t-1)} + f_{B,i,j}^{(t-1)}}{2} \tag{5}$$

If the pixel values $f_{A,i,j}^{(t)}$ and $f_{B,i,j}^{(t)}$ are less than 0, the pixel values $f_{A,i,j}^{(t)}$ and $f_{B,i,j}^{(t)}$ must be set to 0, respectively. If the pixel values $f_{A,i,j}^{(t)}$ and $f_{B,i,j}^{(t)}$ are greater than $M-1$, the pixel values $f_{A,i,j}^{(t)}$ and $f_{B,i,j}^{(t)}$ must be set to $M-1$, respectively.

Two CSP images are obtained after T times iteration of Steps 1 and 2. CSP image A composed of the pixel values $f_{A,i,j}^{(T)}$ is easier to visually recognize photographic image A than photographic image B. On the other hand, CSP image B composed of the pixel values $f_{B,i,j}^{(T)}$ is easier to visually recognize photographic image B than photographic image A. CSP images A and B can recognize photographic images A and B.

3. **Experiments.** We mainly conducted two experiments. We first conducted the experiment that the value of the window size W was changed using photographic images (b) and (c) in Figure 2. We second conducted the experiment that twelve CSP images of six combinations using four photographic images in Figure 2 were visually evaluated. All images in Figure 2 were $512 * 512$ pixels and 256 gradation.

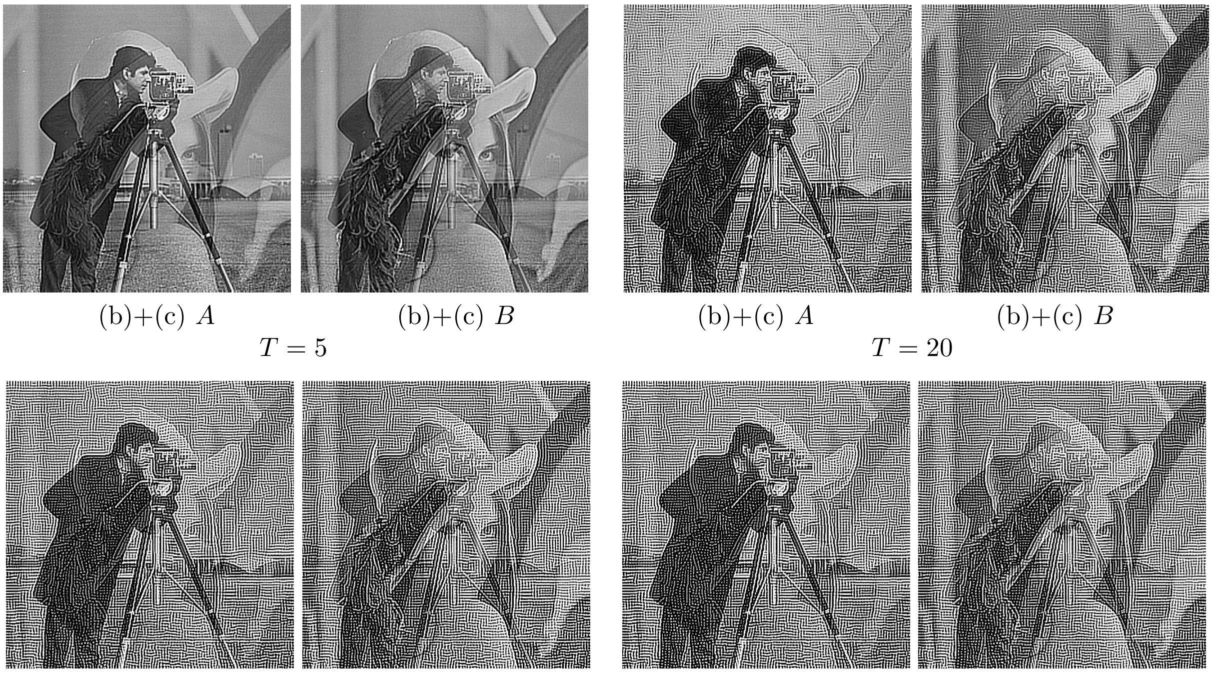
(a) Airplane (b) Cameraman (c) Lenna (d) Lighthouse

FIGURE 2. Photographic images used in the experiments

First, we visually confirmed CSP images changed the value of the iteration number T using photographic images (b) and (c) in Figure 2. We set the value of T to 5, 20, 35 and 50, and set the value of the window size W to 3. The results of the experiment with changing the value of T are shown in Figure 3. In Figure 3, for example, CSP image with a note '(b)+(c) A' indicates CSP image A generated by using photographic images (b) and (c) in Figure 2 as photographic images A and B. As the value of T was larger, CSP patterns became clearer.

Second, we visually confirmed CSP images changed the value of the window size W using photographic images (b) and (c) in Figure 2. We set the value of W to 2, 3, 4 and 5. Since CSP patterns and photographic images were visually recognized well in the previous experiment, we set the value of the iteration number T to 50. The results of the experiment with changing the value of W are shown in Figure 4. In Figure 4, for example, CSP image with a note '(b)+(c) A' indicates CSP image A generated by using photographic images (b) and (c) in Figure 2 as photographic images A and B. As the value of W was larger, CSP patterns became wider. The value of W may be set according to the application of the user.

Finally, we visually confirmed CSP images using four photographic images. Since CSP patterns and photographic images were visually recognized well in the previous experiment, we set the values of the iteration number T and the window size W to 50 and 3,



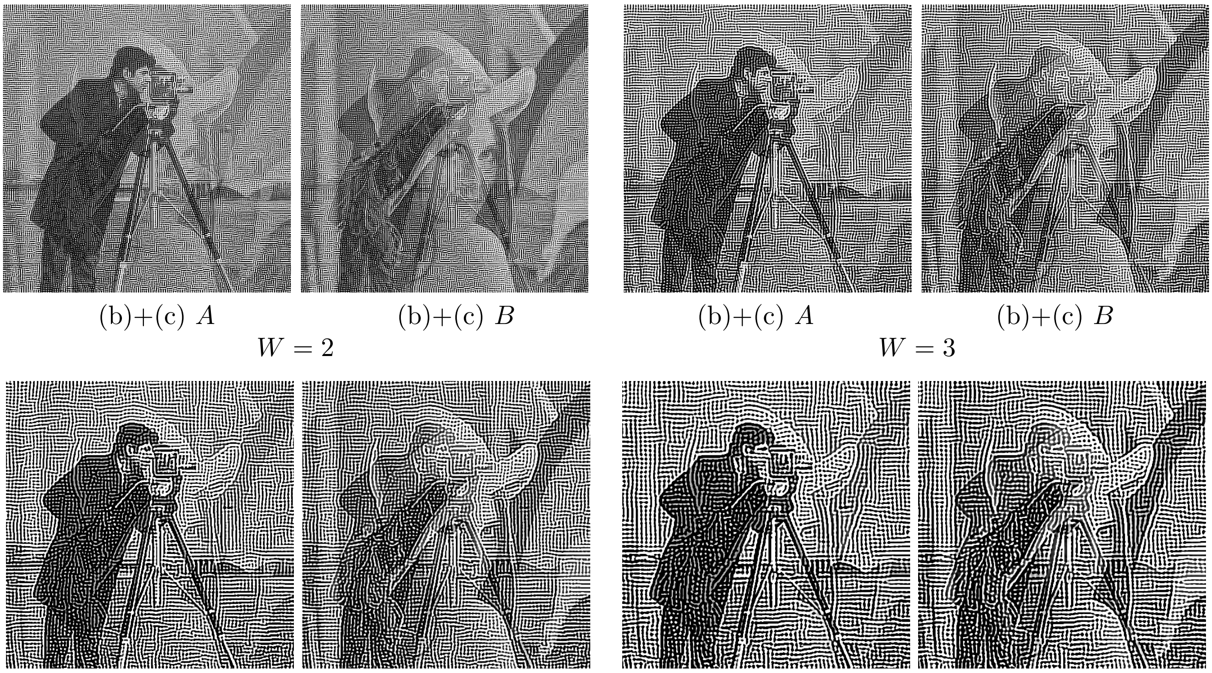
(b)+(c) A (b)+(c) B
$T = 5$

(b)+(c) A (b)+(c) B
$T = 20$

(b)+(c) A (b)+(c) B
$T = 35$

(b)+(c) A (b)+(c) B
$T = 50$

FIGURE 3. CSP images generated by changing the value of the iteration number T



(b)+(c) A (b)+(c) B
$W = 2$

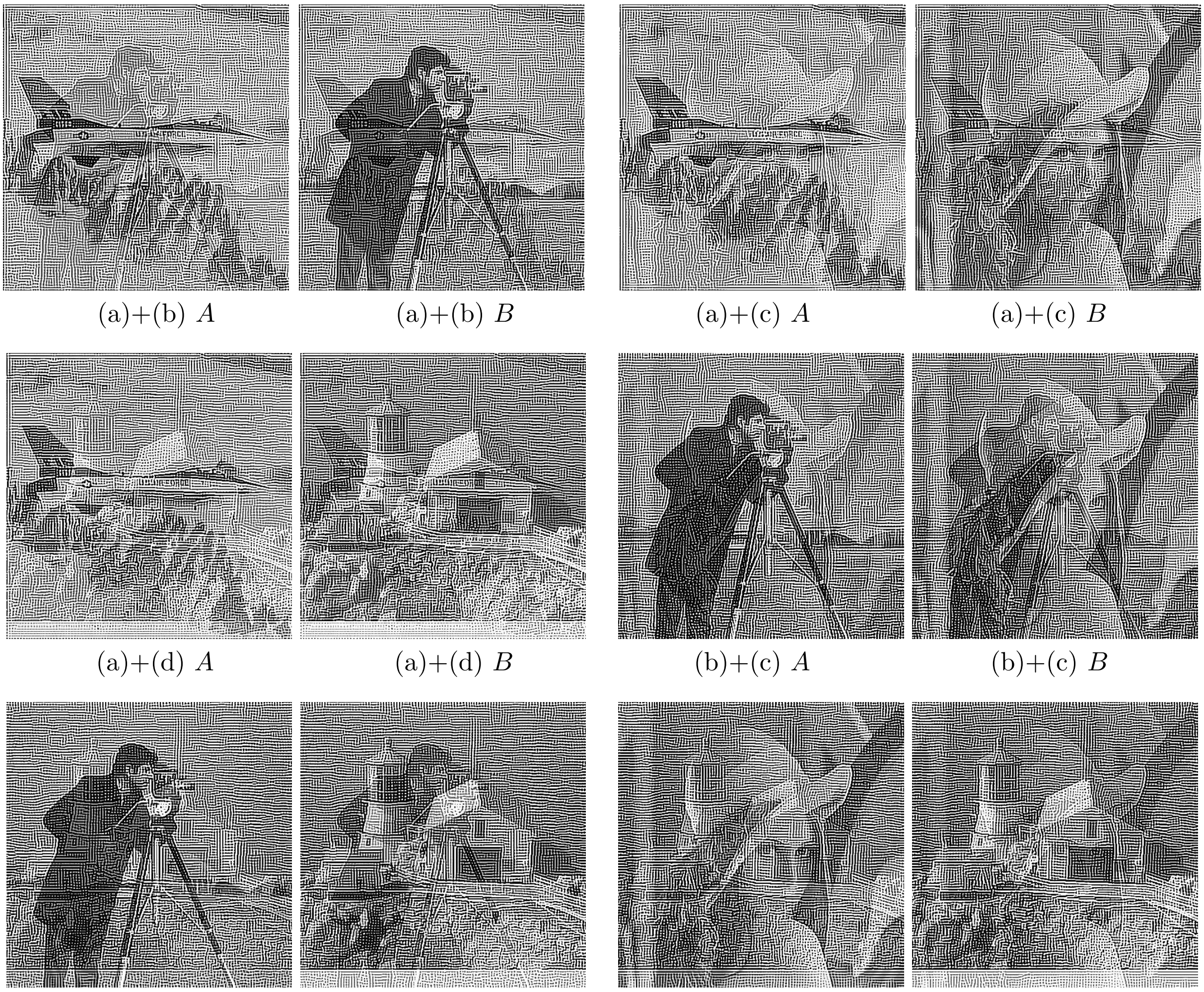
(b)+(c) A (b)+(c) B
$W = 3$

(b)+(c) A (b)+(c) B
$W = 4$

(b)+(c) A (b)+(c) B
$W = 5$

FIGURE 4. CSP images generated by changing the value of the window size W

respectively. The results of the experiment using four photographic images are shown in Figure 5. In Figure 5, for example, CSP image with a note '(a)+(b) B' indicates CSP image B generated by using photographic images (a) and (b) in Figure 2 as photographic images A and B. In all CSP images, our method could connect smoothly SP patterns of two SP images, and two SP images could be visually recognized from one CSP image. CSP images A were easier to visually recognize photographic image A than photographic



(a)+(b) A (a)+(b) B (a)+(c) A (a)+(c) B

(a)+(d) A (a)+(d) B (b)+(c) A (b)+(c) B

(b)+(d) A (b)+(d) B (c)+(d) A (c)+(d) B

Figure 5. CSP images

image B, and CSP images B were easier to visually recognize photographic image B than photographic image A. Compared with the conventional methods [5, 6, 7, 8], the proposed method can synthesize two photographic images, which makes it more fun to create unexpected CSP images depending on the combination of two photographic images.

4. **Conclusions.** We developed a method to synthesize two SP images for the purpose of improving the visual effect of SP images. Our method was executed by devising the averages of the pixel values of two images in the iterative processing using smoothing filter and inverse filter. The effectiveness of our method was visually verified through experiments using various images. The experimental results showed that our method have features that SP patterns of two SP images can be connected smoothly, and two SP images can be visually recognized from one CSP image.

In future works, we will try to apply our method to color photographic images and videos.

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

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