GENERATION OF STONE-STRIPE-LIKE COLOR IMAGES BY BILATERAL MINIMUM AND MAXIMUM FILTERS FOR NON-PHOTOREALISTIC RENDERING

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In the past, a number of non-photorealistic rendering methods that generate stone-stripe-like images from gray-scale photographic images have been proposed. In this paper, the conventional method is extended to a non-photorealistic rendering technique that generates stone-stripe-like color images from color photographic images. In order to validate the effectiveness of the proposed method, examination is conducted using several color photographic images, and the attractiveness of the stone-stripe-like color images generated by the proposed method is evaluated visually.

Key Words **:** non-photorealistic rendering, bilateral minimum and maximum filters, stone stripe

1. INTORODUCTION

Among the various image processing techniques currently in use[1)-4)], non-photorealistic rendering (NPR) is a field of computer graphics in which photographed images are processed and converted to images that resemble paintings, illustrations, or sketches. Such NPR-converted images are frequently seen in our daily lives in television programming, magazines, and web pages.

Among the available NPR techniques, this paper focuses in particular on a method of generating stone-stripe-like[5)] color images. Images of this type imitate the striped patterns that appear when natural rock like malachite or Laguna Agate is cut, as shown in Figure 1. Since striped layers appear along the contour lines of such photographic images as stone-striped patterns, the resulting image allows the viewer to imagine, to some extent, what the original image was like. Moreover, stone-stripe-like images show concentric stone-striped patterns generated at locations other than the contour-line portions of the images (Figure 1, right). The conventional method, which generates stone-stripe-like images through iterative processing employing bilateral minimum and bilateral maximum filters[6)], has previously been applied to gray-scale photographic images.

This paper proposes an extended method that can be used to apply the conventional method to color photographic images. Using this technique, the stone-stripe-like color images show multiple

Fig.1 Examples of stone-striped patterns.

naturally colorful and overlapping stone-striped patterns that have their contour-line portions well preserved, and which are considerably more attractive than gray-scale stone-stripe-like images. In order to validate the effectiveness of the proposed method, examination is conducted with several color images, and attractiveness of the color images generated by the proposed method is evaluated visually.

2. METHOD

Red, green, and blue pixel values in 256 gradations (integer values from 0 to 255) of a color image of $I \times J$ pixels are defined as $f_{R,i,j}$, $f_{G,i,j}$, $f_{B,i,j}$ $(i = 1,2,\cdots,I; \quad j = 1,2,\cdots,J)$, respectively.

First, the mean $f_{i,j}$ of red, green, and blue pixel values is determined as

$(f_{R,i,j} + f_{G,i,j} + f_{B,i,j})/3$, and then, after applying the bilateral minimum and bilateral maximum filters, the pixel values of the image $f_{\min,i,j}$ and $f_{\max,i,j}$ are respectively determined by Equations (1) and (2).

$$f_{\min,i,j} = \frac{\sum_{k=-w}^{w}\sum_{l=-w}^{w} e^{-\alpha f_{i+k,j+l}-\beta(k^2+l^2)-\gamma(f_{i,j}-f_{i+k,j+l})^2} f_{i+k,j+l}}{\sum_{k=-w}^{w}\sum_{l=-w}^{w} e^{-\alpha f_{i+k,j+l}-\beta(k^2+l^2)-\gamma(f_{i,j}-f_{i+k,j+l})^2}} \tag{1}$$

$$f_{\max,i,j} = \frac{\sum_{k=-w}^{w}\sum_{l=-w}^{w} e^{\alpha f_{i+k,j+l}-\beta(k^2+l^2)-\gamma(f_{i,j}-f_{i+k,j+l})^2} f_{i+k,j+l}}{\sum_{k=-w}^{w}\sum_{l=-w}^{w} e^{\alpha f_{i+k,j+l}-\beta(k^2+l^2)-\gamma(f_{i,j}-f_{i+k,j+l})^2}} \tag{2}$$

In these equations, α, β, and γ are positive constants, and w is the window size. With $f_{\min,i,j} - f_{\max,i,j}$ as $d_{i,j}$, and the minima and maxima within $d_{i,j}$ as $d_{\min}$ and $d_{\max}$ respectively, $f_{i,j}$ is updated using Equation (3).

$$f_{i,j} = 255\frac{f_{i,j} - d_{\min}}{d_{\max} - d_{\min}} \tag{3}$$

Gaussian noise is applied selectively to the red, green, and blue pixels of a color image if $f_{i,j}$ is less than S (sites where variation in luminance value of image is_small). Following, $f_{R,i,j}$, $f_{G,i,j}$, and $f_{B,i,j}$ respectively represents the red, green, and blue pixel values of color images augmented with Gaussian noise. Gaussian noise is applied in order to produce stone-striped patterns even at sites where variation in luminance value of image is small. The reason for extracting sites with small luminance variations by employing the mean of red, green, and blue pixel values rather than the respective red, green, and blue of the color image is as follows. Since contour-line portions are different for red, green, and blue, extraction of the mean reduce the possibility of disruption to the contour-line portions when stone-striped patterns are generated.

Next, $f_{i,j}$ is changed respectively to $f_{R,i,j}$, $f_{G,i,j}$, and $f_{B,i,j}$ in Equations (1) and (2), and then derive $f_{R,\min,i,j}$, $f_{R,\max,i,j}$, $f_{G,\min,i,j}$, $f_{G,\max,i,j}$, $f_{B,\min,i,j}$, and $f_{B,\max,i,j}$. $d_{R,i,j}$, $d_{G,i,j}$, and $d_{B,i,j}$ were respectively derived from $f_{R,\max,i,j} - f_{R,\min,i,j}$, $f_{G,\max,i,j} - f_{G,\min,i,j}$, and $f_{B,\max,i,j} - f_{B,\min,i,j}$. Finally, $f_{R,i,j}$, $f_{G,i,j}$, and $f_{B,i,j}$ are updated with Equation (3). By repeating this iterative calculation T times, the stone-stripe-like color image is generated.

Furthermore, to improve the reproducibility of the colors in the stone-stripe-like color image at the time of the conversions of red, green, and blue using Equation (4) in place of Equation (3), the smaller sum of the absolute pixel value differences between the generated and original images are adopted.

$$f_{i,j} = 255\left(1 - \frac{f_{i,j} - d_{\min}}{d_{\max} - d_{\min}}\right) \tag{4}$$

The image generated in this way is called a modified stone-stripe-like color image.

3. EXPERIMENTS

The proposed method is applied to six color images, each 512 × 512 pixels with 256 color levels, as shown in Figure 2. The following examinations are based on Reference 5), using the values $\alpha = 0.1$, $\beta = 0.1$, $\lambda = 0.001$, $w = 5$, $S = 1$, and $T = 5$. The standard deviation for Gaussian noise is 20.

First, the stone-stripe-like color images generated according to the proposed method are shown in Figure 3.As we can be seen in this figure, stone-striped patterns are generated as striped layers along the contour lines of the photographs, while concentric stone-striped patterns are generated at other places in the images. Furthermore, the

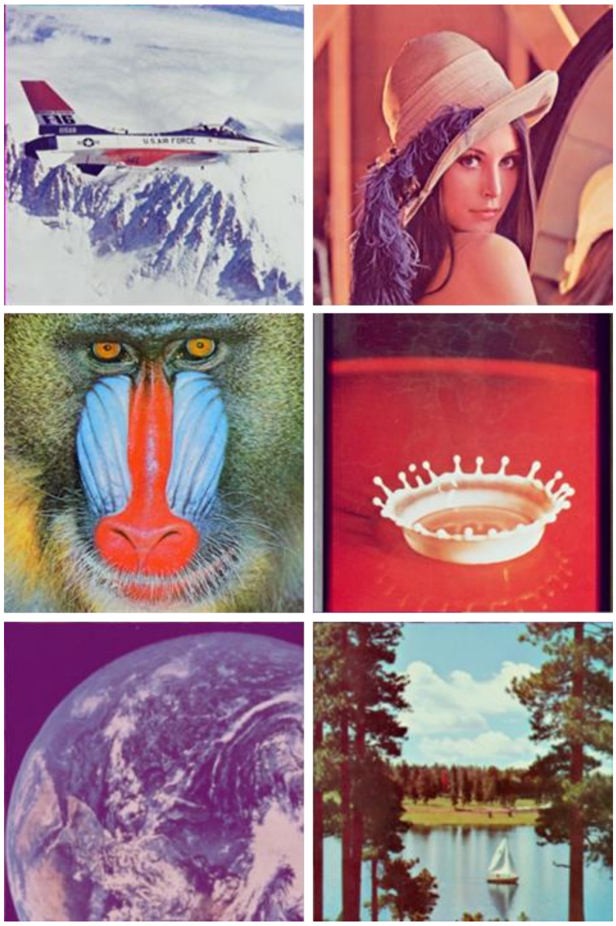

Fig.2 Input color images.

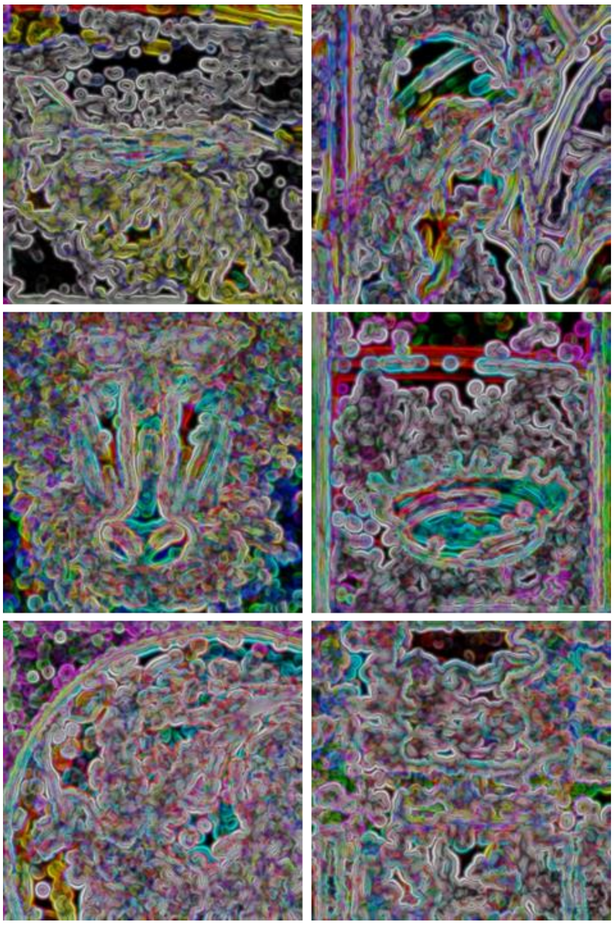

Fig.3 Stone-stripe-like color images.

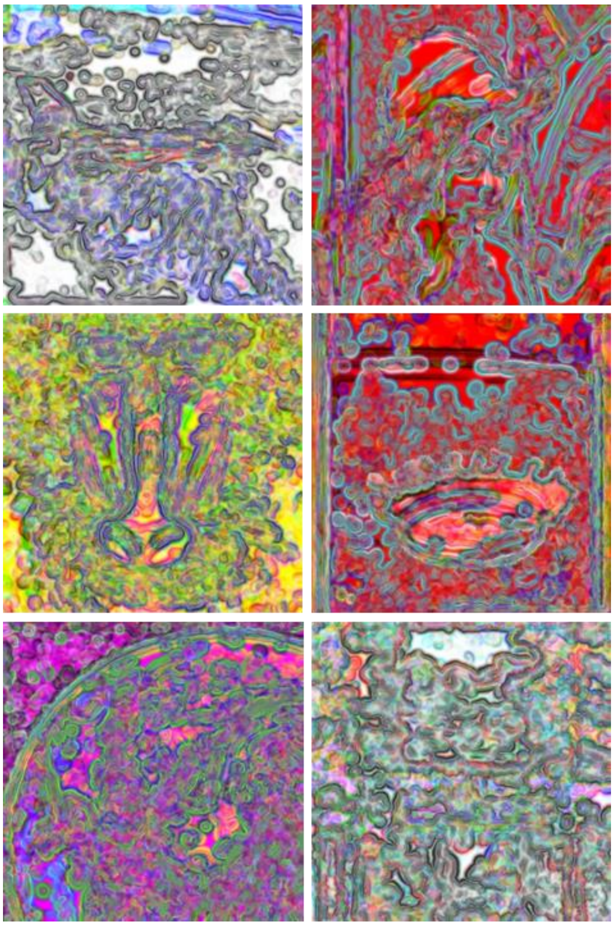

Fig.4 Modified stone-stripe-like color images.

stone-stripe-like color images appear colorful since patterns are naturally overlapping.

As a final examination, we compare stone-stripe-like image generated from a gray-scale image (Figure 5) and stone-stripe-like color images at the upper right of Figure 3 and Figure 4. We conclude that colorizing stone-stripe-like images could improve image attractiveness.

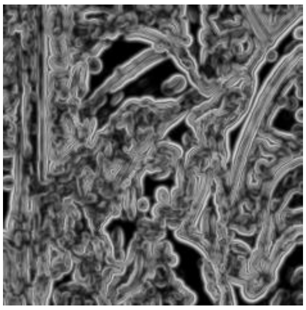

Fig.5 Stone-stripe-like image.

4. CONCLUSION

In this paper, a NPR method that generated stone-stripe-like color images from color photographic images was proposed. In order to validate the effectiveness of the proposed method, examination was conducted with several color images and the attractiveness of the color images generated by the proposed method was evaluated visually. We found that the color images generated by the proposed method had natural overlapping multiple stone-striped patterns, were colorful, and had their contour-line regions preserved. In future work, we intend to study the changes in the generated stone-stripe-like color images by varying the parameter values.

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