LETTER

Generation of Checkered Pattern Images by Iterative Calculation Using Prewitt Filter with Expanded Window Size

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SUMMARY We propose a nonphotorealistic rendering method for generating checkered pattern images from photographic images. The proposed method is executed by iterative calculation using a Prewitt filter with an expanded window size and can automatically generate checkered patterns according to changes in edges and shade of photographic images. To verify the effectiveness of the proposed method, an experiment was conducted using various photographic images. An additional experiment was conducted to visually confirm the checkered pattern images generated by changing the iteration number, window size, and parameter to emphasize the checkered patterns.

key words: nonphotorealistic rendering, checkered pattern, iterative calculation, Prewitt filter

1. Introduction

Nonphotorealistic rendering (NPR) is a field of computer graphics that involves converting photographic images, videos, and three-dimensional data into nonrealistic images, such as oil paintings, watercolors, and cartoons [1]–[4]. A method for generating checkered pattern images from photographic images has been proposed for NPR [5]. Checkered pattern images are expressed by superimposing checkered patterns on photographic images, as shown in Fig. 1. Checkered patterns change the shade of the grid like a checkered flag and curve according to changes in edges and shade of photographic images. The generation of checkered pattern images enables users to convert photographic images captured using a smartphone into checkered pattern images and upload them to a social networking service. It is assumed that checkered patterns are naturally implemented in the image of a person’s clothes, or that checkered patterns are generated from simple images and used as background or in certain parts of comics and illustrations. The conventional method is executed through iterative calculation using iris [6] and inverse [7] filters. However, in this method, checkered patterns are less likely to occur in white (inside the red ellipses in Fig. 1), black (inside the green ellipses in Fig. 1), and fine texture (inside the blue ellipses in Fig. 1) areas. Furthermore, the boundaries of checkered grids are blurred and unclear in the conventional method.

In this study, we propose a method to generate clear checkered patterns in an entire image by iterative calculation using a Prewitt filter with an expanded window size, which hereinafter is referred to as an EWS Prewitt filter. The proposed method has a simpler processing compared with the conventional method, can generate checkered patterns in areas where it is difficult to generate checkered patterns by the conventional method, and can adjust the density of checkered patterns by adding a parameter to express checkered patterns clearly. To verify the effectiveness of the proposed method, we visually compare checkered pattern images generated using the proposed and conventional methods with various photographic images. Furthermore, we conduct an experiment to visually confirm the checkered pattern images generated by changing the iteration number, window size, and parameter to emphasize the checkered patterns.

2. Proposed Method

The proposed method was implemented in two steps: (1) calculate the gradients of the pixel values using the EWS Prewitt filter; (2) convert the images using the gradients of the pixel values. By repeating these two steps, checkered pattern images were generated. The proposed method was...
processed easily.

The Prewitt filter multiplies the pixels in a $3 \times 3$ window centered on the target pixel by the vertical and horizontal coefficients shown in Fig. 2, separately, and sums the results; whereas the EWS Prewitt filter multiplies the pixels in a $(2W+1) \times (2W+1)$ window centered on the target pixel by the vertical and horizontal coefficients, where $W$ is the window size, and sums the results. The total values in the vertical and horizontal directions are denoted by $g_x$ and $g_y$, respectively. The vertical coefficient of the EWS Prewitt filter is $-1$ at the left edge of the window, $1$ at the right edge, and $0$ elsewhere. The horizontal coefficient of the EWS Prewitt filter is $-1$ at the top of the window, $1$ at the bottom, and $0$ elsewhere. An example of the vertical and horizontal coefficients of the EWS Prewitt filter when $W = 2$ is shown in Fig. 3. The EWS Prewitt filter finally calculates $g_x/\sqrt{g_x^2 + g_y^2}$ and $g_y/\sqrt{g_x^2 + g_y^2}$, which represent the vertical and horizontal gradients, respectively.

The detailed procedure of the proposed method is as follows.

Step 0 The input pixel values for the spatial coordinates $(i, j)$ of a grayscale photographic image are denoted by $f_{i,j}$. Subsequently, the pixel values of the image at the $r$th iteration number are denoted by $f^{(r)}_{i,j}$, where $f^{(0)}_{i,j} = f_{i,j}$. The pixel values $f^{(r)}_{i,j}$ have values of $U$ gradient from 0 to $U - 1$.

Step 1 The gradients of the pixel values $g^{(r)}_{x,i,j}$ and $g^{(r)}_{y,i,j}$ are calculated using the EWS Prewitt filter in the following equations:

$$g^{(r)}_{x,i,j} = \sum_{l+j-W}^{l+j+W} (f^{(t-1)}_{i+j, W} - f^{(t-1)}_{i+j, W})$$  

$$g^{(r)}_{y,i,j} = \sum_{k+i-W}^{k+i+W} (f^{(t-1)}_{k+W, j} - f^{(t-1)}_{k+W, j})$$

$$g^{(r)}_{i,j} = \sqrt{g^{(r)}_{x,i,j}^2 + g^{(r)}_{y,i,j}^2}$$

Step 2 The output pixel values $f^{(t)}_{i,j}$ at the $t$th iteration number are calculated using the gradients of the pixel values $g^{(t)}_{x,i,j}$ and $g^{(t)}_{y,i,j}$ in the following equation:

$$f^{(t)}_{i,j} = \begin{cases} f_{i,j} + a g^{(t)}_{x,i,j} & (t \% 2 = 0) \\ f_{i,j} + a g^{(t)}_{y,i,j} & (t \% 2 = 1) \end{cases}$$

where $k$ and $l$ are the positions in the window.

Three Experiments

In the experimental verification, four photographic images (shown in Fig. 4) were used. All photographic images used in the experiments comprised $512 \times 512$ pixels and 256 gradients. Two experiments were conducted: the first experiment was performed to verify changes in the checkered patterns generated by changing the values of the parameters in the proposed method using the Lenna image in Fig. 4 (d); and the second experiment was performed to visually compare the checkered pattern images generated by the proposed and conventional methods with the four photographic images in Fig. 4.

3.1 Experiment with Varying Parameters

Checkered pattern images generated by changing the iteration number $T$ were visually confirmed using the Lenna image. The iteration number $T$ was set to 10, 40, 70, and 100. The other parameters, $W$ and $a$, were set to 3 and 60, respectively. The experimental results are shown in Fig. 5. As the iteration number $T$ increased, the checkered patterns became clearer.

Checkered pattern images generated by changing the window size $W$ were visually confirmed using the Lenna image. The window size $W$ was set to 1, 2, 3, and 4. The other
parameters, $T$ and $a$, were set to 100 and 60, respectively. The experimental results are shown in Fig. 6. The larger the window size $W$, the larger were the checkered patterns.

Checkered pattern images generated by changing the parameter $a$ were visually confirmed using the Lenna image. The parameter $a$ was set to 20, 40, 60, and 80. The other parameters, $T$ and $W$, were set to 100 and 3, respectively.

The experimental results are shown in Fig. 7. The larger the parameter $a$, the deeper were the checkered patterns.

3.2 Comparison between the Proposed and Conventional Methods

The proposed method was applied to four photographic im-
ages, as shown in Fig. 4. The parameters $T$, $W$, and $a$ were set to 100, 3, and 60, respectively. The experimental results are shown in Fig. 8. Checkered pattern images generated from the four photographic images using the conventional method are shown in Fig. 1. The intervals between the checkered patterns in Figs. 1 and 8 were similar. The conventional method generated vertical and horizontal checkered patterns, whereas the proposed method generated diagonal checkered patterns. The proposed method can generate checkered patterns in areas where the conventional method cannot generate them, such as the white (inside the red ellipses in Fig. 1), black (inside the green ellipses in Fig. 1), and fine texture (inside the blue ellipses in Fig. 1) areas. Hence, the proposed method can generate checkered patterns on the entire image. Moreover, the checkered patterns generated using the proposed method were expressed more clearly than those generated using the conventional method.

4. Conclusion

We proposed an NPR method for generating checkered pattern images from photographic images by iterative calculation using the EWS Prewitt filter. To verify the effectiveness of the proposed method, we conducted experiments using four photographic images. Using the proposed method, checkered patterns can be generated in areas where it is difficult to generate checkered patterns by the conventional method. The proposed method can generate checkered patterns on the entire image. In addition, the spacing and density of the checkered patterns can be altered by changing the values of the parameters.

Future studies include extending the proposed method to applications involving color photographic images and videos.

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