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Research Article

Applying Method of Generating Checkered Pattern Images Using Prewitt Filter to RGB-D Images

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ABSTRACT

A non-photorealistic rendering (NPR) method for automatically generating checkered pattern images from gray-scale photographic images using Prewitt filter with an expanded window size has been proposed. In this paper, we propose an extension of the conventional method to apply to RGB-D images. Our method can change the size of the checkered patterns depending on the depth. To verify the effectiveness of our method, we conducted experiments that are visually confirmed the checkered patterns by changing the parameters in our method. As a result of the experiment, it was found that the size of the checkered patterns can be automatically changed according to the depth. Additionally, it was found that the size and density of the checkered patterns can be adjusted by changing the value of the parameters

1. Introduction

NPR [1], [2] combines computer graphics with artistic techniques, and generates non-photorealistic images from photographic images, videos and three dimensional data. The advantage of NPR is that it conveys visual information more effectively and enhances artistry and entertainment by drawing with various emphasis and omissions such as paintings and illustrations. Additionally, the advantage of NPR is that it can generate non-photorealistic images automatically or semi-automatically.

An NPR method for automatically generating checkered pattern images from gray-scale photographic images has been proposed [3], [4]. Checkered pattern images are expressed by superimposing checkered patterns of a certain size on gray-scale photographic images. The conventional method [3] is executed by an iterative process using inverse iris filter, and the conventional method [4] is executed by an iterative process using Prewitt filter with an expanded window size. Since the conventional method [4] can generate the checkered patterns even in areas where the checkered patterns cannot be generated by the conventional method [3], we focus on the conventional method[4] in this paper.

Since it is now possible to acquire RGB-D images with smartphones and stereo cameras, the visual effect of checkered pattern images is expected to be improved by making the conventional method applicable to RGB-D images. RGB-D images have red, green and blue values and depth. Research has already been done to apply the

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method of generating checkered pattern images to videos [5], but not to apply it to RGB-D images.

We in this paper propose an extension of the conventional method to apply to RGB-D images. The checkered patterns generated by our method dose not vary with RGB values, and the size of the checkered patterns varies with the depth. To verify the effectiveness of our method, we conducted experiments to visually confirm the checkered patterns generated by changing the values of the parameters in our method. The experimental result show that our method can generate the checkered pattern images without any shift in the checkered patterns depending on RGB values, and that our method can adjust the size and density of the checkered patterns by changing the values of the parameters.

The rest of this paper is organized as follows. Section 2 describes our method for generating checkered pattern images from RGB-D images. Section 3 shows experimental results, and reveals the effectiveness of the proposed method. Finally, Section 4 concludes this paper.

2. Our method

Our method is implemented in two steps. Step 1 calculates the gradients of the gray-scale pixel values obtained the RGB pixel values using Prewitt filter. Step 2 converts the RGB pixel values using the gradients by changing the window size according to the depth. By repeating Steps 1 and 2, checkered pattern images of our method are generated. A flow chart of the proposed method is shown in Fig. 1.

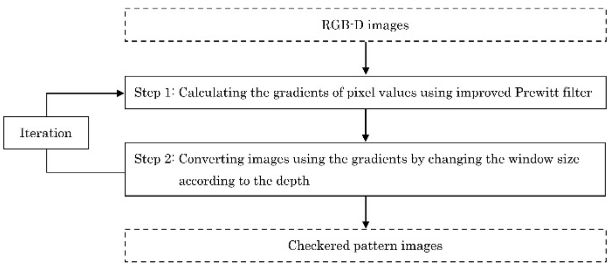


Fig. 1. Flow chart of our method.

The detailed procedure of our method is as follows.

Step 0: The input pixel values (R, G, B) and the depth for spatial coordinates (i, j) of an RGB-D image are denoted by $f_{\mathrm{R},i,j}$, $f_{\mathrm{G},i,j}$, $f_{\mathrm{B},i,j}$ and $f_{\mathrm{D},i,j}$, respectively. Subsequently, the pixel values of the image at the tth iteration number are denoted by $f^{(t)}_{\mathrm{R},i,j}$, $f^{(t)}_{\mathrm{G},i,j}$ and $f^{(t)}_{\mathrm{B},i,j}$, where $f^{(1)}_{\mathrm{R},i,j} = f_{\mathrm{R},i,j}$, $f^{(1)}_{\mathrm{G},i,j} = f_{\mathrm{G},i,j}$ and $f^{(1)}_{\mathrm{B},i,j} = f_{\mathrm{B},i,j}$. The pixel values $f^{(t)}_{\mathrm{R},i,j}$, $f^{(t)}_{\mathrm{G},i,j}$ and $f^{(t)}_{\mathrm{B},i,j}$ have value of U gradation from 0 to $U-1$. The depths $f_{\mathrm{D},i,j}$ are stored in cm and the unit of depths $f_{\mathrm{D},i,j}$ is meters. At each pixel, the window sizes $W_{i,j}$ that determine the size of the checkered patterns are calculated in the following equation:

$$W_{i,j} = W_{\max} - \frac{(W_{\max} - W_{\min})(f_{\mathrm{D},i,j} - f_{\mathrm{D,min}})}{f_{\mathrm{D,max}} - f_{\mathrm{D,min}}} \quad (1)$$

where $f_{\mathrm{D,min}}$ and $f_{\mathrm{D,max}}$ are respectively the minimum and maximum values in the depth $f_{\mathrm{D},i,j}$, and $W_{\min}$ and $W_{\max}$ are respectively the minimum and maximum window sizes set by the user. The smaller the values of the depth $f_{\mathrm{D},i,j}$, the larger the size of the checkered patterns.

Step 1: The gray-scale pixel values $f^{(t)}_{i,j}$ are calculated in the following equation:

$$f^{(t)}_{i,j} = \frac{f^{(t)}_{\mathrm{R},i,j} + f^{(t)}_{\mathrm{G},i,j} + f^{(t)}_{\mathrm{B},i,j}}{3} \quad (2)$$

The gradients of the pixel values $g^{(t)}_{\mathrm{x},i,j}$ and $g^{(t)}_{\mathrm{y},i,j}$ are calculated using Prewitt filter with the expanded window in the following equations:

$$g^{(t)}_{\mathrm{x}',i,j} = \sum_{l=j-W_{i,j}}^{j+W_{i,j}} \left(f^{(t)}_{i-W_{i,j},l} + f^{(t)}_{i+W_{i,j},l}\right) \quad (3)$$

$$g^{(t)}_{\mathrm{y}',i,j} = \sum_{k=i-W_{i,j}}^{i+W_{i,j}} \left(f^{(t)}_{k,j-W_{i,j}} + f^{(t)}_{k,j+W_{i,j}}\right) \quad (4)$$

$$g^{(t)}_{i,j} = \sqrt{{g^{(t)}_{\mathrm{x}',i,j}}^2 + {g^{(t)}_{\mathrm{y}',i,j}}^2} \quad (5)$$

$$g^{(t)}_{\mathrm{x},i,j} = \frac{g^{(t)}_{\mathrm{x}',i,j}}{g^{(t)}_{i,j}} \quad (6)$$

$$g^{(t)}_{\mathrm{y},i,j} = \frac{g^{(t)}_{\mathrm{y}',i,j}}{g^{(t)}_{i,j}} \quad (7)$$

where k and l are the positions in the window.

Step 2: The output pixel values $f^{(t+1)}_{\mathrm{R},i,j}$, $f^{(t+1)}_{\mathrm{G},i,j}$ and $f^{(t+1)}_{\mathrm{B},i,j}$ are calculated using the gradients of the pixel values $g^{(t)}_{\mathrm{x},i,j}$ and $g^{(t)}_{\mathrm{y},i,j}$ in the following equations:

$$f^{(t+1)}_{\mathrm{R},i,j} = \begin{cases} f_{\mathrm{R},i,j} + a g^{(t)}_{\mathrm{x},i,j} & (t \bmod 2 = 0) \\ f_{\mathrm{R},i,j} + a g^{(t)}_{\mathrm{y},i,j} & (t \bmod 2 = 1) \end{cases} \quad (8)$$

$$f^{(t+1)}_{\mathrm{G},i,j} = \begin{cases} f_{\mathrm{G},i,j} + a g^{(t)}_{\mathrm{x},i,j} & (t \bmod 2 = 0) \\ f_{\mathrm{G},i,j} + a g^{(t)}_{\mathrm{y},i,j} & (t \bmod 2 = 1) \end{cases} \quad (9)$$

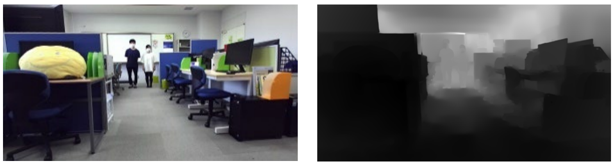
$$f^{(t+1)}_{\mathrm{B},i,j} = \begin{cases} f_{\mathrm{B},i,j} + a g^{(t)}_{\mathrm{x},i,j} & (t \bmod 2 = 0) \\ f_{\mathrm{B},i,j} + a g^{(t)}_{\mathrm{y},i,j} & (t \bmod 2 = 1) \end{cases} \quad (10)$$

where a is a positive constant. If $f^{(t+1)}_{\mathrm{R},i,j}$, $f^{(t+1)}_{\mathrm{G},i,j}$ and $f^{(t+1)}_{\mathrm{B},i,j}$ are less than 0, then $f^{(t+1)}_{\mathrm{R},i,j}$, $f^{(t+1)}_{\mathrm{G},i,j}$ and $f^{(t+1)}_{\mathrm{B},i,j}$ must be set to 0, respectively. If $f^{(t+1)}_{\mathrm{R},i,j}$, $f^{(t+1)}_{\mathrm{G},i,j}$ and $f^{(t+1)}_{\mathrm{B},i,j}$ are greater than $U-1$, then $f_{\mathrm{R},i,j}^{(t+1)}$, $f_{\mathrm{G},i,j}^{(t+1)}$ and $f_{\mathrm{B},i,j}^{(t+1)}$ must be set to $U-1$, respectively.

A checkered pattern image is obtained after Steps 1 and 2, which involves T iterations.

3. Experiments

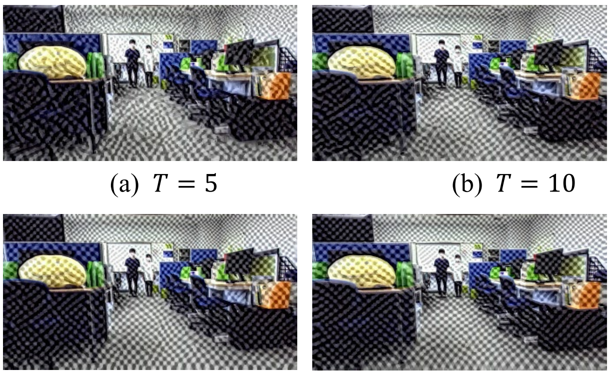
An RGB-D image was obtained using ZED stereo camera. In the following experiments, the RGB-D image in Fig. 2 was used: the left and right sides of Fig. 2 are the RGB and depth images, respectively. In the depth image, a white area indicates a greater distance. The RGB-D image comprised 1280 * 720 pixels and 256 gradations.



(a) RGB image (b) Depth image

Fig. 2. RGB-D image.

Checkered pattern images generated by changing the iteration number T was set to 5, 10, 25 and 50. The other parameters a, W_{min} and W_{max} were set to 60, 2 and 7, respectively. The checkered pattern images generated under these conditions are shown in Fig. 3. As the iteration number T increased, the checkered patterns became clearer. Additionally, looking at Fig. 3 (d) from another point of view, the larger the depth, the smaller the size of the checkered patterns. That is, the size of the checkered patterns could be automagically changed according to the depth.

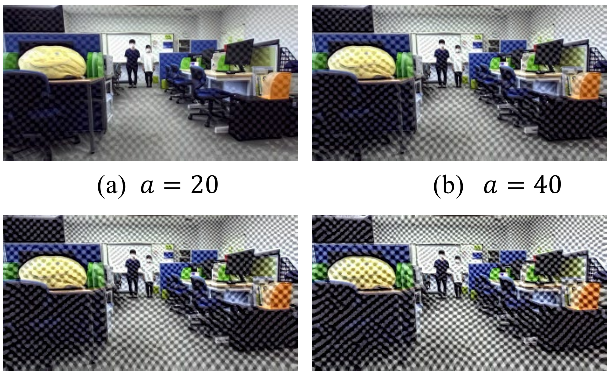


(a) $T=5$ (b) $T=10$

(c) $T=25$ (d) $T=50$

Fig. 3. Checkered pattern images generated by changing the iteration number T.

Checkered pattern images generated by changing the parameter a was set to 20, 40, 60 and 80. The other parameters T, W_{min} and W_{max} were set to 50, 2 and 7, respectively. The checkered pattern images generated under these conditions are shown in Fig. 4. The larger the parameter a, the deeper were the checkered patterns. In all checkered pattern images, the checkered patterns did not vary with RGB values.

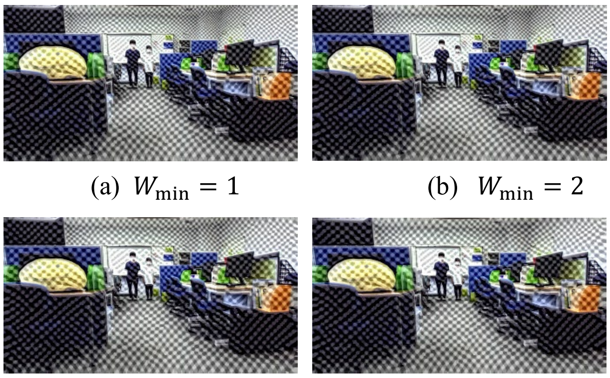


(a) $a=20$ (b) $a=40$

(c) $a=60$ (d) $a=80$

Fig. 4. Checkered pattern images generated by changing the parameter a.

Checkered pattern images generated by changing the window size W_{min} was set to 1, 2, 3 and 4. The other parameters T, a and W_{max} were set to 50, 60 and 7, respectively. The checkered pattern images generated under these conditions are shown in Fig. 5. The smaller the window size W_{min}, the smaller were the size of the checked patterns in the distance. In all checkered pattern images, the checkered patterns did not vary with RGB values.



(a) $W_{\mathrm{min}}=1$ (b) $W_{\mathrm{min}}=2$

(c) $W_{\mathrm{min}}=3$ (d) $W_{\mathrm{min}}=4$

Fig. 5. Checkered pattern images generated by changing the window size W_{min}.

Checkered pattern images generated by changing the window size $W_{\max}$ was set to 5, 6, 7 and 8. The other parameters T, α and $W_{\min}$ were set to 50, 60 and 2, respectively. The checkered pattern images generated under these conditions are shown in Fig. 6. The larger the window size $W_{\max}$, the bigger were the size of the checked patterns nearby. In all checkered pattern images, the checkered patterns did not vary with RGB values.

(a) $W_{\max} = 5$

(b) $W_{\max} = 6$

(c) $W_{\max} = 7$

(d) $W_{\max} = 8$

Fig. 6. Checkered pattern images generated by changing the window size $W_{\max}$.

4. Conclusion

We proposed an NPR method for automatically generating checkered pattern images from RGB-D images. Our method was executed by an iterative process using Prewitt filter with an expanded window size. To verify the effectiveness of our method, we conducted experiments to visually confirm the checkered patterns generated by changing the values of the parameters. The experimental result show that our method can automatically change the checkered patterns according to the depth, and that our method can adjust the size and density of the checkered patterns by changing the values of the parameters.

The future task is to apply the proposed method to RGB-D videos.

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