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A REDUCING-FLICKER METHOD FOR CHARCOAL-DRAWING-LIKE ANIMATION USING INVERSE FILTERING AND SINGULAR VALUE DECOMPOSITION

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Abstract. *A non-photorealistic rendering method has been proposed for generating a charcoal-drawing-like image from a photographic image by an iterative processing using inverse filtering and singular value decomposition. This letter proposes a method for generating a charcoal-drawing-like animation from a photographic video by extending the conventional method. The proposed method can reduce the flicker in the charcoal-drawing-like animation by adding the photographic image and the charcoal-drawing-like image at the one-previous frame to the iterative processing. To verify the degree of reduction of the flicker by the proposed method, quantitative experiments are conducted by the difference between adjacent frames of the charcoal-drawing-like animation. As a result of the experiments, the proposed method has been found that it was possible to reduce the flicker.*
Keywords: Animation, Reducing flicker, Charcoal drawing, Singular value decomposition, Inverse filtering

1. **Introduction.** Various non-photorealistic rendering methods have been proposed for generating a pencil-drawing-like image [1, 2], a watercolor-painting-like image [3], and an oil-painting image-like [4]. These methods are performed by a processing that takes an image, a video, or a three-dimensional data as input. Then, these methods are used in wide range of applications, for example, applications embedded in a personal computer and a portable terminal.

This letter focuses on non-photorealistic rendering to generate a charcoal-drawing-like image. A non-photorealistic rendering method has been proposed for generating the charcoal-drawing-like image [5, 6, 7, 8, 9]. [5] uses contrast enhancement operators on textures and colors, [6] uses luminance of strokes according to luminance of Voronoi regions, [7] uses effects of reflection, shade, atmosphere, depth, and weathering, [8] uses a Barrycentric shader that is based on degree zero B-spline bases function, and [9] uses an iterative processing using inverse filtering [10, 11] and singular value decomposition of a photographic image. This letter focuses on the method of [9] which is easy to process. The charcoal-drawing-like image generated by the method is shown in Figure 1.

Since many photographic videos are used in HP (Home Page) and SNS (Social Networking Service) in recent years, it is possible to improve the visual effect by applying the method [9] to the videos. However, when the charcoal-drawing-like images are generated from each frame of the video and a charcoal-drawing-like animation is generated from the

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(a) Photographic image (b) Charcoal-drawing-like image

FIGURE 1. Charcoal-drawing-like image generated by the method [9]

charcoal-drawing-like images (usual method), flickering occurs in the charcoal-drawing-like animation. Such flickering is known to occur similarly in the animations generated by another non-photorealistic rendering method [12, 13, 14, 15]. [12] uses 3-dimensional particle sets that are rendered as 2-dimensional paint brush strokes, [13] uses a brush stroke with dynamic properties that is governed by user defined and elected styles as well as information extracted from motion information of the video, [14] uses local transfer of the color distributions of the example painting by convolutional neural networks, and [15] uses object flows related regions of the same object across frames.

This letter proposes a method for generating the charcoal-drawing-like animation from the video by extending the method [9]. The proposed method can reduce the flicker in the charcoal-drawing-like animation by adding the photographic image and the charcoal-drawing-like image at the one-previous frame to the iterative processing. The proposed method is simpler to process than the conventional methods [12, 13, 14, 15]. To verify the degree of reduction of the flicker by the proposed method, quantitative experiments are conducted by the difference between adjacent frames of the charcoal-drawing-like animation.

The rest of this letter is organized as follows. Section 2 outlines the method [9] for generating the charcoal-drawing-like image. Section 3 describes the proposed method for generating the charcoal-drawing-like animation. Section 4 shows experimental results, and quantitatively reveals the effectiveness of the proposed method. Finally, Section 5 concludes this letter.

2. **Method [9].** The method [9] generates charcoal-drawing-like images by the iterative process using inverse filtering and singular value decomposition of the photographic image. In the method, singular value decomposition is first performed on the photographic image, and a reconstructed image is computed using several singular values and vectors. Next, the reconstructed image is restored to the photographic image by inverse filtering. The restored image includes a restoration error. By repeating the above processes, the charcoal-drawing-like image is generated with the emphasized restoration error.

The detailed procedure of the method is shown as follows.

Step 0: Let the input pixel values on coordinates (i, j) of the photographic image be $f_{i,j}$ $(i = 1, 2, \dots, I;\ j = 1, 2, \dots, J)$. The pixel values $f_{i,j}$ have value of 256 gradation from 0 to 255.

Step 1: Singular value decomposition of $f_{i,j}$ is computed. Let the k-th singular value and vectors be λ_k, $u_k = [u_{k,1}, u_{k,2}, \dots, u_{k,I}]$, and $v_k = [v_{k,1}, v_{k,2}, \dots, v_{k,J}]$ respectively, where $u_k u_k^T = 1$ and $v_k v_k^T = 1$. Let the output pixel value of the reconstructed image using from the first to K-th singular values and vectors be $SVD_K(f_{i,j})$.

$$SVD_K(f_{i,j}) = \sum_{k=1}^{K} \lambda_k v_k^T u_k \tag{1}$$

Step 2: The pixel values $f_{i,j}^{(m)}$ using inverse filtering are computed as

$$f_{i,j}^{(m)} = f_{i,j}^{(m-1)} - SVD_K\left(f_{i,j}^{(m-1)}\right) + f_{i,j} \tag{2}$$

where m $(m = 1, 2, \ldots)$ is the number of iterations and $f_{i,j}^{(0)} = f_{i,j}$. The pixel values $f_{i,j}^{(m)}$ are set to 0 if their values are less than 0, and set to 255 if their values are greater than 255.

Step 3: The charcoal-drawing-like image is obtained after M times iteration of Steps 1 and 2.

3. **Proposed Method.** When the charcoal-drawing-like images are generated from each frame of the video and a charcoal-drawing-like animation is generated from the charcoal-drawing-like images (usual method), flickering occurs in the charcoal-drawing-like animation. Therefore, it is necessary to reduce the flicker in the charcoal-drawing-like animation.

The proposed method can reduce the flicker in the charcoal-drawing-like animation by adding the photographic image and the charcoal-drawing-like image at the one-previous frame to the iterative processing. Let input pixel values on coordinates (i, j) and the lth frame of the video be $f_{l,i,j}$ $(i = 1, 2, \ldots, I;\ j = 1, 2, \ldots, J;\ l = 1, 2, \ldots, L)$. The proposed method uses the following three ideas (Figure 2).

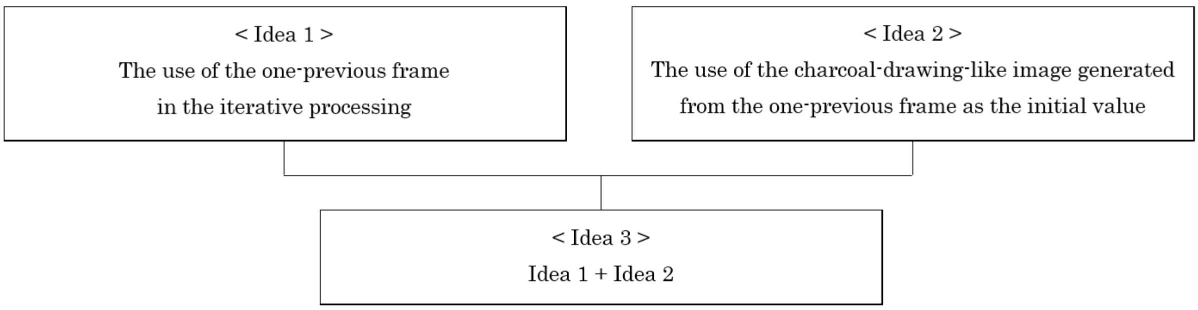

Figure 2. Ideas of the proposed method

Idea 1: In Equation (2), instead of the image $f_{l,i,j}$, the one-previous frame $f_{l-1,i,j}$ is used at a rate of once per N times in the iterative processing. In the calculation of the first frame of the video, only image $f_{1,i,j}$ is used in the iterative processing. A conceptual diagram of Idea 1 is shown in Figure 3.

Idea 2: Instead of using the image $f_{l,i,j}$ as the initial value $f_{l,i,j}^{(0)}$ for the iterative processing, the charcoal-drawing-like image generated from the one-previous frame (the $l-1$th frame) is used as the initial value $f_{l,i,j}^{(0)}$. In the calculation of the first frame of the video, the image $f_{1,i,j}$ is used as the initial value $f_{1.i,j}^{(0)}$. A conceptual diagram of Idea 2 is shown in Figure 4.

Idea 3: Ideas 1 and 2 are combined.

4. **Experiments.** The proposed method was applied to an Edo-wind-chime video which has been developed by the video-database-working group affiliated with the technical group of pattern recognition and media understanding [16]. The Edo-wind-chime video is 553 frames, 30 frames/second, $352 * 240$ pixels, and 256 tones. To verify the degree of

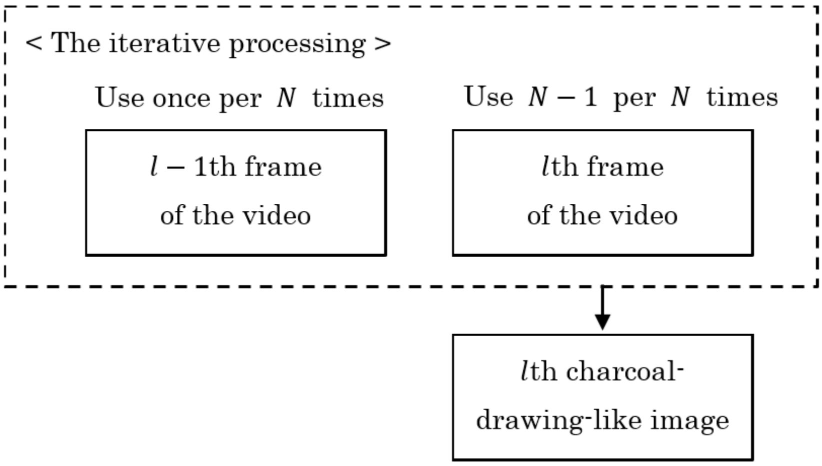

FIGURE 3. Conceptual diagram of Idea 1

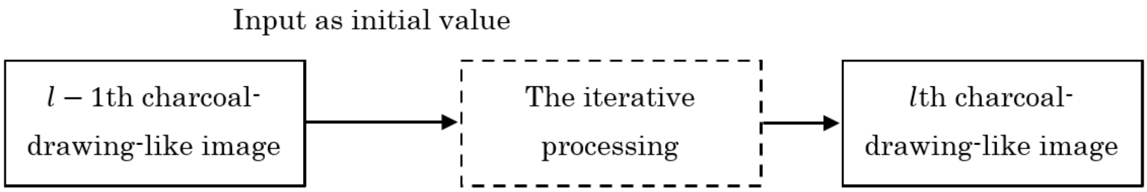

FIGURE 4. Conceptual diagram of Idea 2

reduction of the flicker by the proposed method, the quantitative experiments were conducted by the difference between adjacent frames of the charcoal-drawing-like animation. The experiments of the usual method, Idea 1, Idea 2, and Idea 3 were conducted. For the experiments, referring to [9], the values of the parameters K and M were set to 20 and 50, respectively.

4.1. **Method of quantitative evaluation.** In the quantitative experiments, the means of the absolute difference in pixel value between adjacent frames of the charcoal-drawing-like animation were calculated, and then the mean of all of these frame means (MV-F) was calculated. MV-F is an index for evaluating the magnitude of the flicker. Since flickering occurs as a result of changes in the fine charcoal-drawing-like patterns between adjacent frames, flickering lessens in the charcoal-drawing-like animation as AV-F becomes smaller. On the other hand, flickering increases as AV-F becomes larger.

The means of the absolute difference in pixel value between frames of the charcoal-drawing-like animation and the video were calculated, and then the mean of all of these frame means (MV-V) was calculated. MV-V is an index for evaluating the similarity with the video. As AV-V becomes smaller, the charcoal-drawing-like animation and the video are more similar. On the other hand, as AV-V becomes larger, the charcoal-drawing-like animation and the video are less similar.

4.2. **Experiment of the usual method.** The experiment of the usual method was conducted quantitatively. MV-F and MV-V of the usual method are shown in Table 1. MV-F and MV-V were 60.447 and 53.061, respectively.

TABLE 1. MV-F and MV-V of the usual method

MV-F	MV-V
60.447	53.061

4.3. **Experiment of Idea 1.** The experiment of Idea 1 was conducted quantitatively by varying the values of the parameter M to 2, 3, 4, 5, and 6. MV-F and MV-V of Idea 1 are shown in Table 2. MV-F increased as M becomes larger. MV-V tended to increase as M becomes larger. Since MV-F of Idea 1 was smaller than MV-F of the usual method, Idea 1 could reduce the flicker more than the usual method. Since MV-V of Idea 1 was approximately the same value of MV-V of the usual method, both charcoal-drawing-like animations reproduced the video as much as possible. Thus, the value of the parameter M must be set to 2.

Table 2. MV-F and MV-V of Idea 1

N	MV-F	MV-V
2	47.384	48.557
3	49.701	49.265
4	51.205	49.447
5	51.390	53.051
6	53.277	50.088

4.4. **Experiment of Idea 2.** The experiment of Idea 2 was conducted quantitatively. MV-F and MV-V of Idea 2 are shown in Table 3. MV-F and MV-V were 55.582 and 54.264, respectively. Since MV-F of Idea 2 was slightly smaller than MV-F of the usual method, Idea 2 could slightly reduce the flicker more than the usual method. Since MV-V of Idea 2 was approximately the same value of MV-V as the usual method, both charcoal-drawing-like animations reproduced the video as much as possible.

Table 3. MV-F and MV-V of Idea 2

MV-F	MV-V
55.582	54.264

4.5. **Experiment of Idea 3.** The experiment of Idea 3 was conducted quantitatively. The value of the parameter M was set to 2. MV-F and MV-V of Idea 3 are shown in Table 4. MV-F and MV-V were 46.586 and 51.973, respectively. Since MV-F of Idea 3 was the smallest in all methods, Idea 3 could best reduce the flicker. Since MV-V of Idea 3 was approximately the same value of MV-V as the usual method, both charcoal-drawing-like animations reproduced the video as much as possible. Thus, it is best to use Idea 3 to reduce the flicker.

Table 4. MV-F and MV-V of Idea 3

MV-F	MV-V
46.586	51.973

5. **Conclusions.** This letter proposed a method for generating a charcoal-drawing-like animation from a photographic video while reducing flicker. To reduce the flicker, the proposed method used three ideas. The first idea used a one-previous frame of the video in the iterative processing. The second idea used a charcoal-drawing-like image generated from the one-previous frame as an initial value. The third idea combined the first and second ideas. The proposed method was applied to an Edo-wind-chime video, and quantitative experiments were conducted by the difference between adjacent frames of the

charcoal-drawing-like animation. The experiments showed that the proposed method can reduce the flicker in the charcoal-drawing-like animation.

Subjects for future work are to apply the proposed method to other photographic videos and to extend the proposed method to a color photographic video.

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