ICIC Express Letters
Volume **14**, Number **5**, May **2020**

 ISSN 1881-803X
pp. **443–448**

GENERATION OF EDGE-PRESERVING CREPE-PAPER-LIKE IMAGES USING SMOOTHING FILTER AND CORRELATION COEFFICIENT

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Received October 2019; accepted January 2020

Abstract. *We propose a non-photorealistic rendering (NPR) for generating edge-preserving crepe-paper-like (EPCPL) images from gray-scale photographic images. EPCPL images are like photographic images drawn on crepe pagers, and the patterns of crepe pager are occurring along the edges in photographic images. The proposed method is executed by an iterative calculation using smoothing filter and correlation coefficient. The proposed method is simple and easy to implement, and can generate EPCPL patterns by preserving the edges in photographic images. To validate the effectiveness of the proposed method, experiments using various photographic images are conducted. Results show that the proposed method can generate impressive EPCPL images in which the edges are preserved.*

Keywords: Non-photorealistic rendering, Edge preservation, Crepe paper, Smoothing filter, Correlation coefficient

1. **Introduction.** In NPR using a computer, there is a method using image processing [1, 2, 3] for converting photographic images into non-photorealistic images, and various methods have been proposed so far [4, 5, 6, 7]. Gatys et al. [4] proposed a neural algorithm of artistic style that can separate and recombine the image content and style of natural images, Qian et al. [5] proposed a non-photorealistic rendering method that automatically generates a gourd pyrography style from photographic images, Martin et al. [6] surveyed methods for the digital simulation of hand-made stippling, and Wu [7] proposed a framework of generative art by combining the techniques of saliency detection and stroke-based art. In recent years, non-photorealistic images generated by these methods are becoming common on television, magazines, and the Internet. Among these methods, there is an NPR method for generating crepe-paper-like (CPL) images [8]. Crepe papers are fine paper with fine wrinkles as shown in Figure 1, and can also have textures like Japanese papers. CPL images are like photographic images drawn on crepe papers, and fine irregularities of wrinkles are expressed. The conventional method is executed by an iterative calculation using inverse Roberts filter and histogram equalization.

In this paper, we propose an NPR method for generating EPCPL images with high edge preservation in CPL images from gray-scale photographic images. The proposed method is executed by the iterative calculation using smoothing filter and correlation coefficient. Therefore, it is simple to process and easy to implement. Turing pattern [13] is famous as patterns generated by iterative calculations such as the proposed method, and has been researched for a long time. This research can also contribute to the research field related to such iterative calculations. The proposed method is expressed with emphasis on fine irregularities on wrinkles rather than the conventional method, and can automatically

DOI: 10.24507/icicel.14.05.443

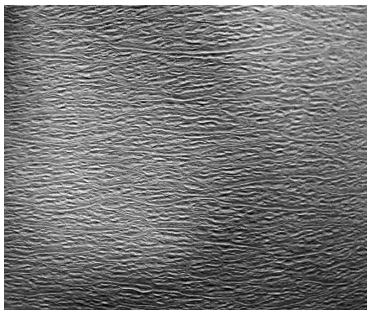

FIGURE 1. Crepe paper

generate EPCPL patterns along the edges in photographic images. To visually verify the effectiveness of the proposed method, experiment using Lenna image is conducted to investigate the changes of EPCPL patterns generated by varying the parameters in the proposed method. In addition, the proposed method is applied to various images. As a result of the experiments, it is revealed that EPCPL patterns can be automatically generated on the whole image.

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

2. **Proposed Method.** The proposed method is executed by the iterative processing using smoothing filter [9, 10] and correlation coefficient [11, 12]. A flow chart of the proposed method is shown in Figure 2. It turns out that the proposed method does not use particularly difficult processing.

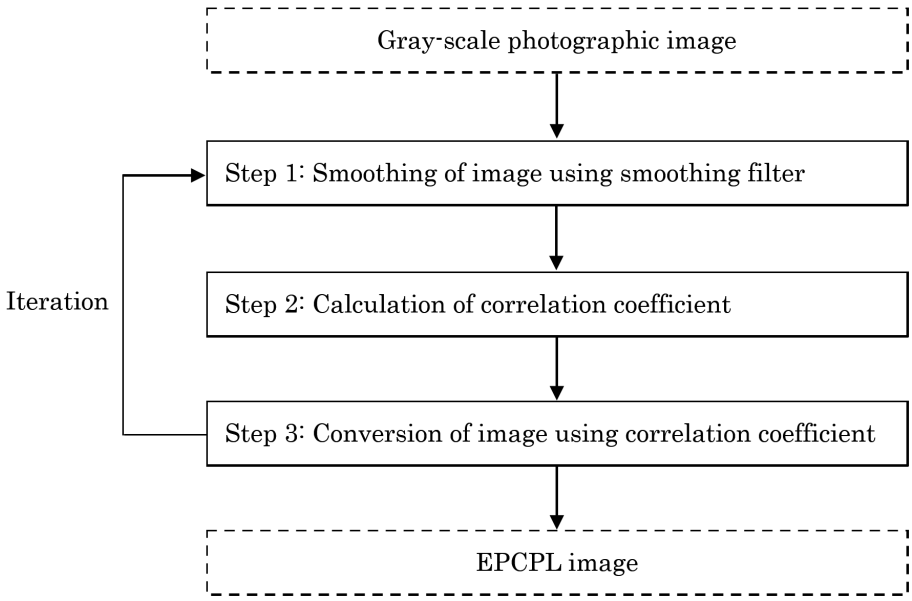

FIGURE 2. Flow chart of the proposed method

Details of the steps in Figure 2 are shown below.

Step 0: Let the input pixel values on coordinates (i, j) of a gray-scale photographic image be $f_{i,j}$. The pixel values $f_{i,j}$ have value of U gradation from 0 to $U-1$.

Step 1: The pixel values $f_{i,j}^{(t-1)}$ are smoothed using pixels adjacent to pixel (i, j), where t is the iteration number and $f_{i,j}^{(0)} = f_{i,j}$. The smoothed pixel values $s_{i,j}^{(t)}$ are calculated as follows.

$$s_{i,j}^{(t)} = \frac{1}{9}\sum_{k=-1}^{1}\sum_{l=-1}^{1} f_{i+k,j+l}^{(t-1)} \tag{1}$$

where (k, l) is a plurality of spatial coordinates of the pixels included in the range of ± 1 around the spatial coordinate (i, j).

Step 2: The correlation coefficients $c_{i,j}^{(t)}$ for each pixel are calculated using the pixel values $f_{i,j}$ and $s_{i,j}^{(t)}$ as follows.

$$c_{i,j}^{(t)} = \frac{\sum_{k=-1}^{1}\sum_{l=-1}^{1}(f_{i+k,j+l} - a_{i,j})\left(s_{i+k,j+l}^{(t)} - a_{i,j}^{(t)}\right)}{\sqrt{\sum_{k=-1}^{1}\sum_{l=-1}^{1}(f_{i+k,j+l} - a_{i,j})^2}\sqrt{\sum_{k=-1}^{1}\sum_{l=-1}^{1}\left(s_{i+k,j+l}^{(t)} - a_{i,j}^{(t)}\right)^2}} \tag{2}$$

$$a_{i,j} = \frac{1}{9}\sum_{k=-1}^{1}\sum_{l=-1}^{1} f_{i+k,j+l} \tag{3}$$

$$a_{i,j}^{(t)} = \frac{1}{9}\sum_{k=-1}^{1}\sum_{l=-1}^{1} s_{i+k,j+l}^{(t)} \tag{4}$$

Step 3: The pixel values $f_{i,j}^{(t)}$ are calculated using the input pixel values $f_{i,j}$ and the correlation coefficients $c_{i,j}^{(t)}$ as follows.

$$f_{i,j}^{(t)} = \begin{cases} f_{i,j} + a{c_{i,j}^{(t)}}^3 & (t \text{ modulo } 2 = 0) \\ f_{i,j} - a{c_{i,j}^{(t)}}^3 & (t \text{ modulo } 2 = 1) \end{cases} \tag{5}$$

where a is a positive constant. $f_{i,j}^{(t)}$ must be set to 0 in case $f_{i,j}^{(t)}$ is smaller than 0, and $f_{i,j}^{(t)}$ must be set to set to $U - 1$ in case $f_{i,j}^{(t)}$ is greater than $U - 1$. The process from Steps 1 to 3 is repeated T times. An image composed of pixel values $f_{i,j}^{(T)}$ is an EPCPL image.

3. **Experiments.** The proposed method was applied to Lenna image with 512×512 size and 256 gradation. Lenna image is shown in Figure 3. The changes in appearance to EPCPL images were visually assessed as the values of the parameters T and a were varied. EPCPL images for $T = 5$, 10, 20 and 40 and $a = 90$ are shown in Figure 4. As shown, as W became bigger, EPCPL patterns became finer. EPCPL images for $a = 30$, 60, 90 and 120 and $T = 40$ are shown in Figure 5. As shown, as a became bigger, EPCPL patterns were emphasized and became clearer.

The proposed method and the conventional method [8] were compared using Lenna image. Although the conventional method [8] used color photographic images, the generated color CPL image was converted into the gray-scale CPL image for comparison.

FIGURE 3. Lenna image

(a) $T = 5$ (b) $T = 10$ (c) $T = 20$ (d) $T = 40$

FIGURE 4. EPCPL images for $T = 5$, 10, 20 and 40 and $a = 90$

(a) $a = 30$ (b) $a = 60$ (c) $a = 90$ (d) $a = 120$

FIGURE 5. EPCPL images for $a = 30$, 60, 90 and 120 and $T = 40$

FIGURE 6. CPL image generated by the conventional method [8]

The gray-scale CPL image is shown in Figure 6. As a result of the comparison, EPCPL patterns of the proposed method were generated more along the edges than CPL patterns of the conventional method [8].

The proposed method was applied to eight photographic images with 512×512 size and 256 gradation besides Lena image. Eight photographic images are shown in Figure 7. Since EPCPL patterns and Lenna image were visually recognized well in the previous experiment, the values of T and a were set to 100 and 90, respectively. The results are shown in Figure 8. In all cases, EPCPL patterns could be automatically generated along the edges in photographic images. However, EPCPL patterns were less likely to occur in areas with fine textures and white and black areas.

4. **Conclusions.** This paper proposed an NPR method for generating EPCPL images from gray-scale photographic images by an iterative calculation using smoothing filter and correlation coefficient. The proposed method had features that the processing is simple and EPCPL patterns can be automatically generated by preserving the edges in photographic images. In the experiments using Lenna image and other photographic

FIGURE 7. Various photographic images

FIGURE 8. EPCPL images

images, it was clarified that the proposed method can practically realize these features. However, it was found out that EPCPL patterns are less likely to occur in areas with fine textures and white and black areas.

A subject for future study is to be able to generate EPCPL patterns in areas with fine textures and white and black areas. Another task is to expand the proposed method for application to color photographic images.

Acknowledgment. This work was supported by JSPS KAKENHI Grant Number JP19 K12664.

REFERENCES

[1] P. Maniriho and T. Ahmad, High quality PVM based reversible data hiding method for digital images, *International Journal of Innovative Computing, Information and Control*, vol.15, no.2, pp.667-680, 2019.

[2] R. Matsumura and A. Hanazawa, Human detection using color contrast-based histograms of oriented gradients, *International Journal of Innovative Computing, Information and Control*, vol.15, no.4, pp.1211-1222, 2019.
[3] H. Yang, W. Gan, F. Chen and X. Li, Face recognition using shearlets edges fusion, *International Journal of Innovative Computing, Information and Control*, vol.15, no.4, pp.1309-1322, 2019.
[4] L. A. Gatys, A. S. Ecker and M. Bethge, Image style transfer using convolutional neural networks, *The IEEE Conference on Computer Vision and Pattern Recognition*, pp.2414-2423, 2016.
[5] W. Qian, D. Xu, K. Yue, Z. Guan, Y. Pu and Y. Shi, Gourd pyrography art simulating based on non-photorealistic rendering, *Multimedia Tools and Applications*, vol.76, no.13, pp.14559-14579, 2017.
[6] D. Martin, G. Arroyo, A. Rodriguez and T. Isenberg, A survey of digital stippling, *Computers & Graphics*, vol.67, pp.24-44, 2017.
[7] T. Wu, Saliency-aware generative art, *Proc. of the 10th International Conference on Machine Learning and Computing*, pp.198-202, 2018.
[8] T. Hiraoka and K. Urahama, Generating crepe-paper-like images by inverse Roberts filter, *The Journal of the Society for Art and Science*, vol.15, no.3, pp.120-124, 2016.
[9] T. Hiraoka, Generation of zebra-pattern images using smoothing filter in consideration of scanning order and unsharp mask, *ICIC Express Letters*, vol.13, no.9, pp.807-813, 2019.
[10] T. Hiraoka and Y. Tsurunari, Generation of fingerprint-pattern-like images using shifted smoothing filter, *ICIC Express Letters*, vol.13, no.12, pp.1133-1138, 2019.
[11] T. Hiraoka, T. Katayama and K. Urahama, Generation of parallel-fine-curve-line images by iterative calculation using correlation coefficient, *ICIC Express Letters*, vol.12, no.11, pp.1131-1136, 2018.
[12] T. Hiraoka, T. Katayama and K. Urahama, Generation of concrete-wall-like images by autocorrelation coefficient and inverse filtering, *ICIC Express Letters*, vol.13, no.2, pp.127-132, 2019.
[13] A. M. Turing, The chemical basis of morphogenesis, *Philosophical Transactions of the Royal Society of London, Series B, Biological Sciences*, vol.237, no.641, pp.37-72, 1952.