ICIC Express Letters
Volume 11, Number 10, October 2017

ICIC International ©2017 ISSN 1881-803X
pp. 1533–1538

METHOD FOR MOVING MOIRE PATTERNS ON MOIRE-LIKE IMAGES

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Received May 2017; accepted July 2017

Abstract. *A non-photorealistic rendering method has been proposed that uses the staircasing effect of a bilateral filter to generate moire-like images from photographic images. The moire-like images are used as special effects in magazines and television, as well as on the Internet. However, there are instances when moving the moire pattern on a moire-like image is preferable to enhance the visual effect in television or on the Internet. This paper proposes a simple method for moving the moire pattern on a moire-like image by combining simple animations. To assess the effectiveness of the proposed method, the smoothness of the changes during moire pattern movement on a moire-like image is visually evaluated by testing on a gray-scale image of Lenna.*
Keywords: Non-photorealistic rendering, Moire, Bilateral filter, Movement

1. **Introduction.** Non-photorealistic rendering (NPR) methods that use computers to generate non-photorealistic images, such as oil paintings [1, 2], pencil sketches [3, 4], and charcoal drawings [5, 6], from photographic images have gained attention in recent years. This has led to the packaging of NPR into many software packages such as Adobe Photoshop or Clip Studio Paint Pro; NPR has also become available in handheld devices such as smartphones and tablets, allowing many non-experts to freely use it.

An NPR method using the staircasing effect [7] of bilateral filter [8], which smooths images while preserving edges, has been proposed to generate moire-like images [9, 10] from photographic images. The moire-like images are used as special effects in magazines and television, as well as on the Internet. However, there are instances when moving the moire pattern on the moire-like image is preferable to enhance the visual effect in television or on the Internet. In recent years, studies to add motion to photographic images have gained attention [11].

This paper proposes a simple method for moving the moire pattern on the moire-like image by combining simple animations ("synthesized animation"). To assess the effectiveness of the proposed method, the smoothness of the changes during moire pattern movement on the moire-like image is visually evaluated by testing using the gray-scale image of Lenna shown in Figure 1. Synthesized animations generated using sine waves are used in this study. A newly added parameter for the proposed method is also used to verify the movement of the moire pattern with the change in parameter values.

Methods for generating animation from a single photographic image include a method that moves the object using physical simulation using dynamic models [12, 13], a method that generates natural waves using $1/f^{\beta}$ noise [14, 15], and a method that moves the

FIGURE 1. Image of Lenna

target region using video animation [16, 17]. The method proposed in the present paper involves simpler processing because it uses simple animation that is not $1/f^{\beta}$ noise and video animation, and it does not use physical simulation. From a view point of simplicity of process, there is a method that moves the object in photographic images according to a simple formula [18]. Although the simple conventional method is applicable to the object, the proposed method is applicable to the whole photographic images.

The rest of this paper is organized as follows. Section 2 describes the simple method for moving the moire pattern on the moire-like image by combining synthesized animations. Section 3 shows experimental results, demonstrates that the moire pattern can be moved smoothly using the proposed method, and reveals how to change in movement of the moire pattern with a change in the newly added parameter values. Finally, Section 4 concludes this paper.

2. **Proposed Method.** The proposed method can be broadly described as comprising three processes. In the first process, an image with staircasing effect is generated using the photographic image and each frame of the synthesized animation filtered with bilateral filter ("synthesized bilateral filter"). In the second process, the image obtained from the first process is filtered with a filter that combines the synthesized bilateral filter and unsharp masking ("reverse synthesized bilateral filter") to generate a moire-like image that magnifies the staircasing effect. The first and second processes generate a moire-like image for each synthesized animation frame. In the third process, a moving animation of the moire pattern on the moire-like image is generated by successively displaying the moire-like image for each synthesized animation frame obtained from the first and second processes.

2.1. **Synthesized bilateral filter.** Let the input pixel value of the spatial coordinates (i, j) for the photographic image be $f_{i,j}$ and that for the sth frame of the synthesized animation be $p_{s,i,j}$. The lengthwise and crosswise dimensions of the photographic image and synthesized animation are taken as equal. The output pixel value $f_{s,i,j}^{(t)}$ of the photographic image and the sth frame of the synthesized animation filtered with the synthesized bilateral filter (where t is the iteration number) is calculated as follows:

$$f_{s,i,j}^{(t)} = \frac{\displaystyle\sum_{k=i-w}^{i+w} \sum_{l=j-w}^{j+w} e^{-F_{s,i,j}^{(t-1)}} f_{s,i,j}^{(t-1)}}{\displaystyle\sum_{k=i-w}^{i+w} \sum_{l=j-w}^{j+w} e^{-F_{s,i,j}^{(t-1)}}} \tag{1}$$

$$F_{s,i,j}^{(t-1)} = \alpha\left((i-k)^2 + (j-l)^2\right) + \beta\left(f_{s,i,j}^{(t-1)} - f_{s,k,l}^{(t-1)}\right)^2 + \gamma\left(p_{s,i,j} - p_{s,k,l}\right)^2 \tag{2}$$

where $f_{s,i,j}^{(0)} = f_{i,j}$; α, β, and γ are positive constants; and w is the window size. The synthesized bilateral filter is the conventional bilateral filter with the third term on the right-hand side of Equation (2), $\gamma(p_{s,i,j} - p_{s,k,l})^2$, added. When the change in pixel value of the synthesized animation is small compared to the photographic image, the value of γ must be increased relative to β to enlarge the movement of the moire pattern on the moire-like image.

2.2. **Reverse synthesized bilateral filter.** If the image $f_{s,i,j}^{(T_1)}$ after filtering the photographic image T_1 times with the synthesized bilateral filter is $g_{s,i,j}^{(0)}$, then the output pixel value for the reverse synthesized bilateral filter $g_{s,i,j}^{(t)}$ (where t is the iteration number) is calculated as follows:

$$g_{s,i,j}^{(t)} = 2g_{s,i,j}^{(t-1)} - \frac{\displaystyle\sum_{k=i-w}^{i+w} \sum_{l=j-w}^{j+w} e^{-G_{s,i,j}^{(t-1)}} g_{s,i,j}^{(t-1)}}{\displaystyle\sum_{k=i-w}^{i+w} \sum_{l=j-w}^{j+w} e^{-G_{s,i,j}^{(t-1)}}} \tag{3}$$

$$G_{s,i,j}^{(t-1)} = \alpha\left((i-k)^2 + (j-l)^2\right) + \beta\left(g_{s,i,j}^{(t-1)} - g_{s,k,l}^{(t-1)}\right)^2 + \gamma\left(p_{s,i,j} - p_{s,k,l}\right)^2 \tag{4}$$

where again α, β, γ, and w are the same as in Equations (1) and (2). The image after filtering T_2 times with the reverse synthesized bilateral filter is the moire-like image corresponding to the sth frame of the synthesized animation.

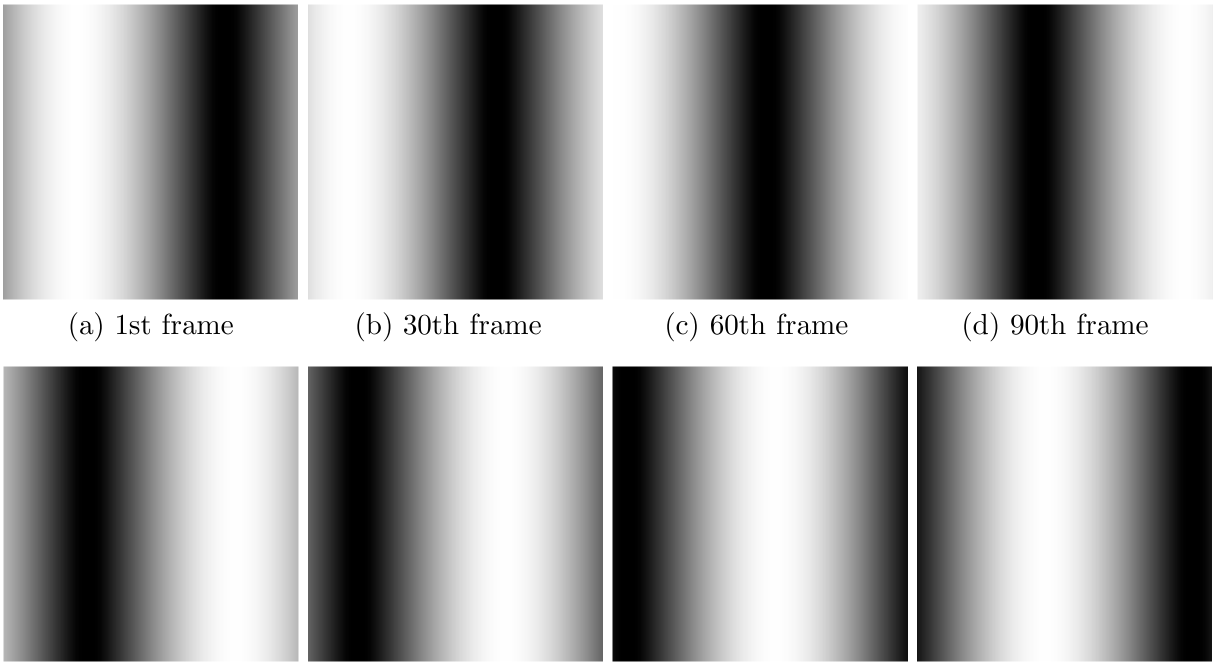
2.3. **Moving animation of moire patterns.** The synthesized bilateral filter is applied to the photographic image, then the reverse synthesized bilateral filter is applied, and finally, the moire-like images are generated for synthesized animation frame. The moving animation of the moire pattern on the moire-like image is generated by successively displaying the moire-like image for each synthesized animation frame. The moving animation is in accordance with the change between the synthesized animation frames.

3. **Test.** The proposed technique was applied to a 256*256 pixel gray-scale image of Lenna. The parameters α, β, w, T_1, and T_2 of the conventional bilateral filter were given values of 0.01, 0.01, 10, 10, and 40, respectively, based on previous studies [9, 10]. The synthesized animation was produced by moving sine waves with an amplitude of 128 pixels and wavelength of 256 pixels toward the left one pixel at a time for each frame, with the same pixel value in the longitudinal direction. The 1st, 30th, 60th, 90th, 120th, 150th, 180th, and 210th frames of the synthesized animation are shown in Figure 2.

First, the moire pattern on the moire-like image was moved with a value of 0.01 for the newly added parameter to the proposed technique γ. The 1st, 30th, 60th, 90th, 120th, 150th, 180th, and 210th frames of the animation moving the moire pattern on the moire-like image are shown in Figure 3. The resulting animation exhibited a smoothly moving moire pattern.

Next, the moire pattern on the moire-like image was moved using values of 0.1 and 0.001 for γ. The 1st, 30th, 60th, 90th, 120th, 150th, 180th, and 210th frames of the animation moving the moire pattern on the moire-like image are shown in Figures 4 and 5 respectively for 0.1 and 0.001. Figure 3 through 5 show that using a larger value of γ produces a narrower moire pattern interval, whereas using a value that is too small stops the moire pattern movement. This suggests that although it may also depend on the synthesized animation used, a value of around 0.01 for γ is adequate for the level of change in pixel value of the synthesized animation in Figure 2.

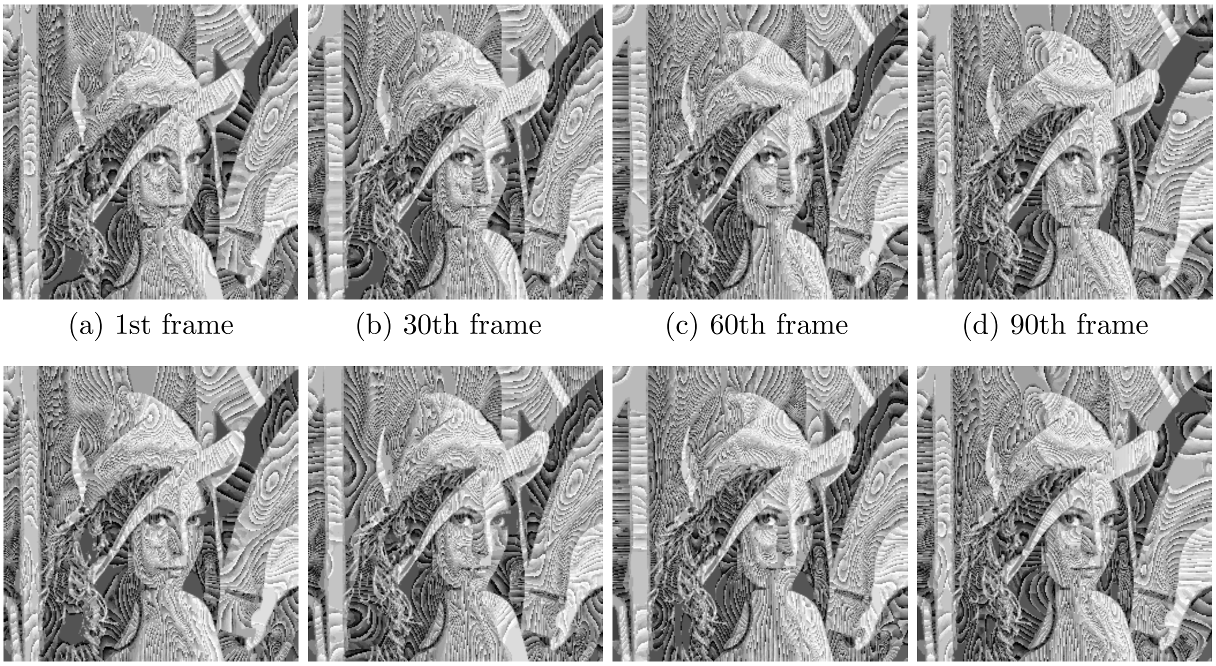
Since the conventional methods [12, 13, 16, 17, 18] are focused on moving the object or the target region, it is not suitable for moving the moire pattern of the whole photographic



(a) 1st frame (b) 30th frame (c) 60th frame (d) 90th frame

(e) 120th frame (f) 150th frame (g) 180th frame (h) 210th frame

Figure 2. Synthesized animation used in this study



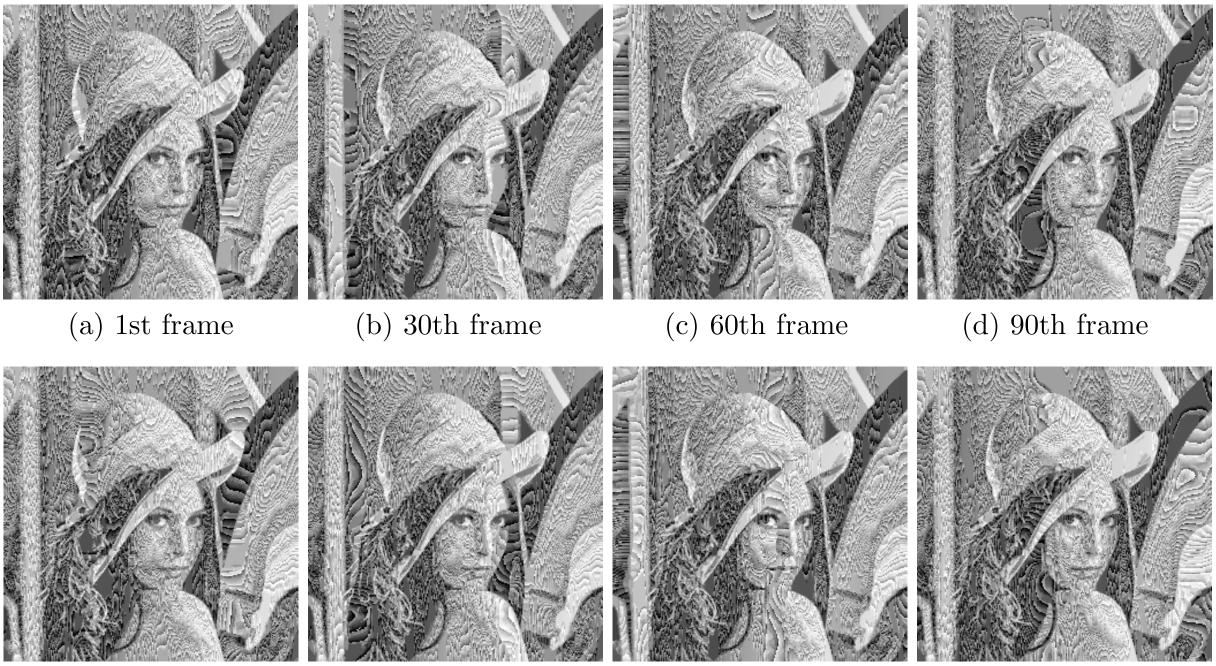
(a) 1st frame (b) 30th frame (c) 60th frame (d) 90th frame

(e) 120th frame (f) 150th frame (g) 180th frame (h) 210th frame

Figure 3. Animation moving the moire pattern on the moire-like image ($\gamma = 0.01$)

image as the proposed method. Since the conventional methods using $1/f^{\beta}$ noise [14, 15] are considered to be able to move the moire pattern of the whole photographic image, it is necessary to investigate the difference in the change in the motion of the moire pattern generated by the proposed method and the conventional methods as a future study.

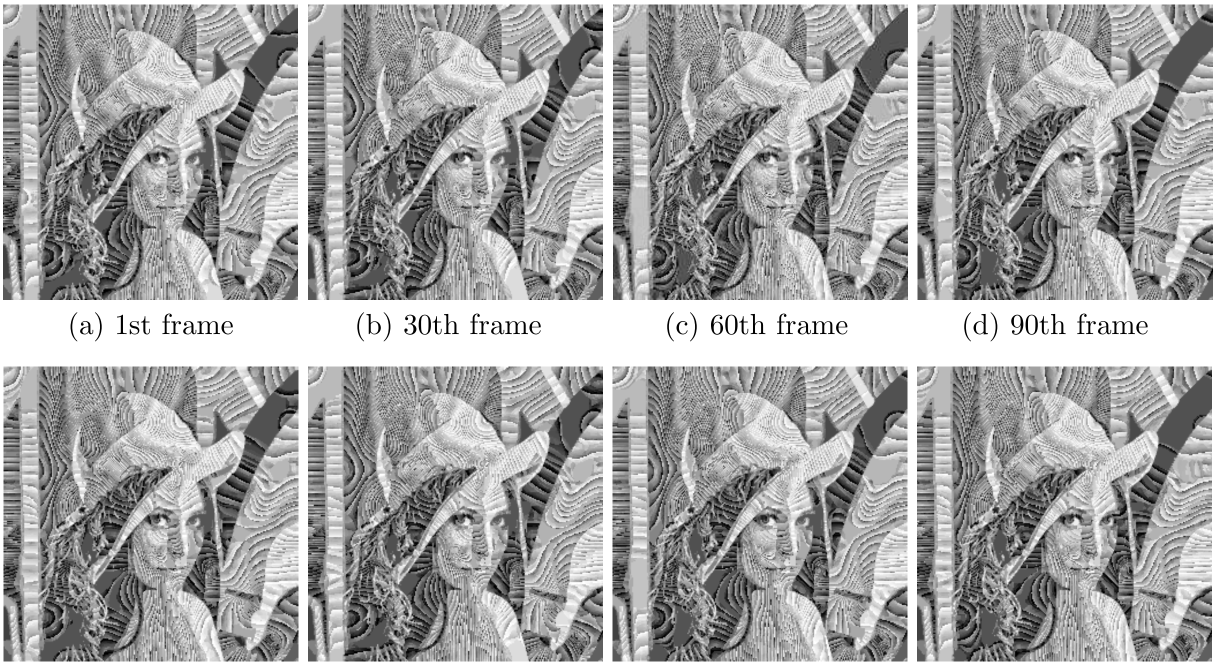
4. **Conclusions.** A simple method was proposed for moving the moire pattern on a moire-like image by combining synthesized animations. Effectiveness of the proposed



(a) 1st frame (b) 30th frame (c) 60th frame (d) 90th frame

(e) 120th frame (f) 150th frame (g) 180th frame (h) 210th frame

Figure 4. Animation moving the moire pattern on the moire-like image ($\gamma = 0.1$)



(a) 1st frame (b) 30th frame (c) 60th frame (d) 90th frame

(e) 120th frame (f) 150th frame (g) 180th frame (h) 210th frame

Figure 5. Animation moving the moire pattern on the moire-like image ($\gamma = 0.001$)

method was assessed visually with respect to smoothness of changes during moire pattern movement of a moire-like image by testing on a gray-scale image of Lenna. Synthesized animations generated using sine waves were used. The test results demonstrated that the moire pattern can be moved smoothly using the proposed method. A newly added parameter for the proposed method was also used to verify the change in movement of the moire pattern with a change in parameter values.

Further necessary studies include performing the test using images other than Lenna, using other synthesized animations, and using color images. The further study is also to investigate the difference in the change in the motion of the moire pattern generated by the proposed method and the conventional methods [14, 15].

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