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GENERATION OF POP ART-LIKE IMAGES USING BINOMIAL DISTRIBUTION

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Abstract. *We propose a non-photorealistic rendering method for generating pop art-like images from photographic images using binomial distribution. Our pop art-like images are represented by a small number of colors and by different colors from reality. Our method has features that it is simple to process, can automatically remove the fine color changes of photographic images, and can automatically preserve the edges of photographic images. In order to verify the effectiveness of our method, the changes of pop art-like images generated by changing the parameters of our method are visually confirmed using Lenna image. Experiments using various photographic images are also conducted. Potential applications of our method range from the Internet, television and magazines.*
Keywords: Non-photorealistic rendering, Pop art, Binomial distribution, Automatic generation

1. **Introduction.** Pop art is an art movement of modern and contemporary arts that was born in Britain in the mid 1950s under the influence of American popular culture [1]. Pop art is expressed under the theme of mass production and mass consumption societies, and is treated in magazines, advertisements, cartoons and press photographs. As pop art artists, Roy Lichtenstein and Andy Warhol, who were active in the United States in the 1960s, were famous and influenced the world. Roy Lichtenstein drew comics and commercial ads with sharp outlines, color planes and dots. Andy Warhol mainly handled celebrities and products produced by mass media and popular culture, and created a large number of works using silkscreens. Andy Warhol's works are represented by a small number of colors and by different colors from reality, and are offset and have inked out intentionally.

In recent years, computer graphics technology called non-photorealistic rendering has attracted attention, which generates non-photorealistic images close to expressions such as pictures and illustrations from photographic images, videos and three-dimensional models [2, 3, 4, 5]. Non-photorealistic rendering includes techniques to imitate traditional art expressions such as oil paintings, pencil drawings and paper mosaics, techniques using human illusions [6, 7, 8], and animation techniques using cartoon techniques [9, 10]. Haeberli [2] verified the paint-rendering techniques that controlled the color, shape, size and orientation of individual brush strokes, Lansdown and Schofield [3] surveyed more than 15 of non-photorealistic rendering techniques and defined the framework for non-photorealistic rendering techniques that distinguishes them from techniques focused on photorealism, Martin et al. [4] surveyed the techniques for the digital simulation of hand-made stippling, Lawonn et al. [5] surveyed the illustrative rendering techniques for three-dimensional surface models, Inglis et al. [6] proposed the Op art rendering technique with straight lines

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and curves, Ahmed [7] proposed the Op art/labyrinth rendering technique with Truchet-like tiles, Hiraoka et al. [8] proposed Op art rendering technique with moire-like patterns, Dalstein et al. [9] introduced the vector animation complex that is a data structure for vector graphics animation designed to support the modeling of time-continuous topological events, and Fan et al. [10] proposed the technique for dealing with the articulation, expressive deformation and occlusion that are common when hand-drawn characters are deformed. Such non-photorealistic images are often seen on the Internet, television and magazines.

In this paper, we develop a non-photorealistic rendering method for generating pop art-like images from photographic images by image processing technology [11, 12, 13]. Our pop art-like images are represented by a small number of colors and by different colors from reality. Our method is implemented by image processing using binomial distribution. The feature of our method is that it is simple to process, can automatically remove the fine color changes of photographic images, and can automatically preserve the edges of photographic images. As a conventional method, a method to generate pop art-like images from photographic images has been proposed [14], but the processing is complicated because it uses Scalable Vector Graphics as a prototype representation in evolutionary art. Also, our method can generate pop art-like images with different expressions from the conventional method. To verify the effectiveness of our method, we conducted experiments using Lenna image and other photographic images.

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

2. **Our Method.**

Our method generates pop art-like images from photographic images. Our method is executed in three steps. In the first step, processing using binomial distribution is performed on each pixel of photographic images. In the second step, photographic images are converted using the values calculated in the first step. In the third step, eight pop art-like images are generated by inverting the red, green and blue pixel values of the images converted in the second step. Our method dose not use particularly difficult processing, and then is easy to implement. A flow chart of our method is shown in Figure 1.

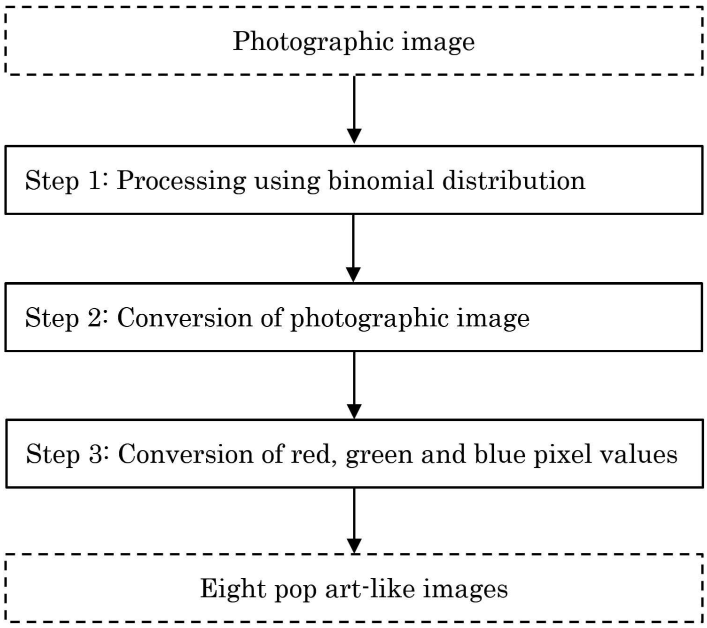


FIGURE 1. Flow chart of our method

Details of the procedure in Figure 1 are explained below.

Step 0: The input pixel values (R, G, B) for spatial coordinates (i, j) of a photographic image are defined as $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$. In compliance with image data widely used in the world, the pixel values $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ have value of U gradation from 0 to $U-1$.

Step 1: The averages a_R, a_G and a_B of the pixel values $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ are calculated, respectively. For red, green and blue images, the numbers n_R, n_G and n_B of pixels smaller than a_R, a_G and a_B are obtained, respectively. For pixels in the window of W pixels, the sets $n_{R,i,j}$, $n_{G,i,j}$ and $n_{B,i,j}$ of the numbers of pixels smaller than the averages a_R, a_G and a_B are obtained, respectively. The values $d_{R,i,j}$, $d_{G,i,j}$ and $d_{B,i,j}$ are calculated using binomial distribution in the window of W pixels as the following equations.

$$d_{R,i,j} = \sum_{k \in n_{R,i,j}} {}_{W^2}\mathrm{C}_k \left(\frac{n_R}{W^2}\right)^k \left(1 - \frac{n_R}{W^2}\right)^{W^2-k} \tag{1}$$

$$d_{G,i,j} = \sum_{k \in n_{G,i,j}} {}_{W^2}\mathrm{C}_k \left(\frac{n_G}{W^2}\right)^k \left(1 - \frac{n_G}{W^2}\right)^{W^2-k} \tag{2}$$

$$d_{B,i,j} = \sum_{k \in n_{B,i,j}} {}_{W^2}\mathrm{C}_k \left(\frac{n_B}{W^2}\right)^k \left(1 - \frac{n_B}{W^2}\right)^{W^2-k} \tag{3}$$

where k is the number of pixels smaller than the averages a_R, a_G and a_B in the window in Equations (1), (2) and (3), respectively. The minimum values $d_{R,\min}$, $d_{G,\min}$ and $d_{B,\min}$ and the maximum values $d_{R,\max}$, $d_{G,\max}$ and $d_{B,\max}$ in the values $d_{R,i,j}$, $d_{G,i,j}$ and $d_{B,i,j}$ are obtained, respectively.

Step 2: The pixel values $f_{R,i,j}$, $f_{G,i,j}$ and $f_{B,i,j}$ are converted to $h_{R,i,j}$, $h_{G,i,j}$ and $h_{B,i,j}$ as the following equations.

$$h_{R,i,j} = f_{R,i,j} + \alpha \left(1 - 2\frac{d_{R,i,j} - d_{R,\min}}{d_{R,\max} - d_{R,\min}}\right) \tag{4}$$

$$h_{G,i,j} = f_{G,i,j} + \alpha \left(1 - 2\frac{d_{G,i,j} - d_{G,\min}}{d_{G,\max} - d_{G,\min}}\right) \tag{5}$$

$$h_{B,i,j} = f_{B,i,j} + \alpha \left(1 - 2\frac{d_{B,i,j} - d_{B,\min}}{d_{B,\max} - d_{B,\min}}\right) \tag{6}$$

where α is a positive constant. In case $h_{R,i,j}$, $h_{G,i,j}$ and $h_{B,i,j}$ are less than 0, then $h_{R,i,j}$, $h_{G,i,j}$ and $h_{B,i,j}$ must be set to 0, respectively. In case $h_{R,i,j}$, $h_{G,i,j}$ and $h_{B,i,j}$ are greater than $U-1$, then $h_{R,i,j}$, $h_{G,i,j}$ and $h_{B,i,j}$ must be set to $U-1$, respectively.

Step 3: The pixel values $h'_{R,i,j}$, $h'_{G,i,j}$ and $h'_{B,i,j}$ are calculated by inverting the pixel values $h_{R,i,j}$, $h_{G,i,j}$ and $h_{B,i,j}$ as the following equations.

$$h'_{R,i,j} = U - 1 - h_{R,i,j} \tag{7}$$

$$h'_{G,i,j} = U - 1 - h_{G,i,j} \tag{8}$$

$$h'_{B,i,j} = U - 1 - h_{B,i,j} \tag{9}$$

Eight pop art-like images are generated by combining the red pixel values $h_{R,i,j}$ and $h'_{R,i,j}$, the green pixel values $h_{G,i,j}$ and $h'_{G,i,j}$, and the blue pixel values $h_{B,i,j}$ and $h'_{B,i,j}$.

3. **Experiments.** We mainly conducted two experiments. The first experiment with changing the values of the parameters in our method was conducted using Lenna image shown in Figure 2. The second experiment was conducted to verify visually that pop art-like images can be generated using Lenna image and three photographic images shown in

FIGURE 2. Lenna image

(a) Earth (b) Mandrill (c) Parrots

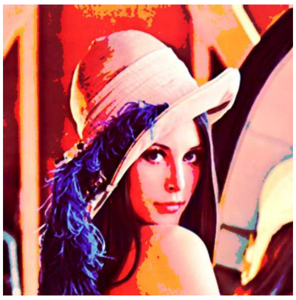
FIGURE 3. Various photographic images

Figure 3. All photographic images used in the experiments were 512×512 pixels and 256 gradation.

We visually confirmed pop art-like images changed the values of the parameters W and α in our method using Lenna image. In order to visually recognize changes in the appearance of pop art-like images when the values of W and α are changed, we set the value of W to 3, 7 and 11, and set the value of α to 50, 100 and 150. The results of the experiment with changing the values of W and α are shown in Figure 4. Figure 4 shows pop art-like images when the red, green and blue pixel values are not inverted. The larger the value of W, the smoother the color changing boundaries were expressed. The larger the value of α, the smaller the number of colors and the less like the original image. The user may adjust the values of W and α according to the applications.

We visually confirmed pop art-like images using Lenna image and other three photographic images. Since pop art-like patterns were visually recognized well in the previous experiment, we set the values of the parameters W and α to 7 and 100, respectively. The results of the experiment using four photographic images are shown in Figure 5 to Figure 8. All pop art-like images could be represented by a small number of colors and by different colors from reality, and then could gave an impression of pop art created with silkscreens. In addition, our method could automatically remove the fine color changes of photographic images, and could automatically preserve the edges of photographic images. Compared with images in the literature [14], our method could generate colorful images with higher saturation than the conventional method.

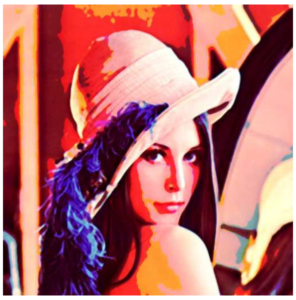
4. **Conclusions.** We developed a non-photorealistic rendering method for generating pop art-like images from photographic images. Our pop art-like images are represented by a small number of colors and by different colors from reality. Our method was executed by processing using binomial distribution. Our method had three features: it is simple to process, can automatically remove the fine color changes of photographic images, and can automatically preserve the edges of photographic images. The effectiveness of our method



(a) $W = 3$, $\alpha = 50$

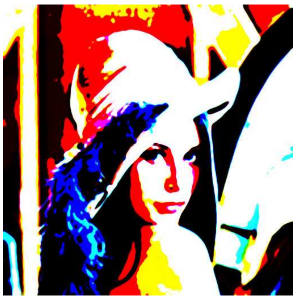
(b) $W = 3$, $\alpha = 100$

(c) $W = 3$, $\alpha = 150$

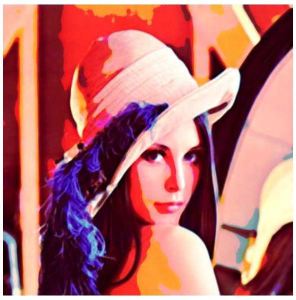


(d) $W = 7$, $\alpha = 50$

(e) $W = 7$, $\alpha = 100$



(f) $W = 7$, $\alpha = 150$



(g) $W = 11$, $\alpha = 50$

(h) $W = 11$, $\alpha = 100$

(i) $W = 11$, $\alpha = 150$

Figure 4. Pop art-like images generated by changing the values of the parameters W and α

Figure 5. Pop art-like images (Lenna)

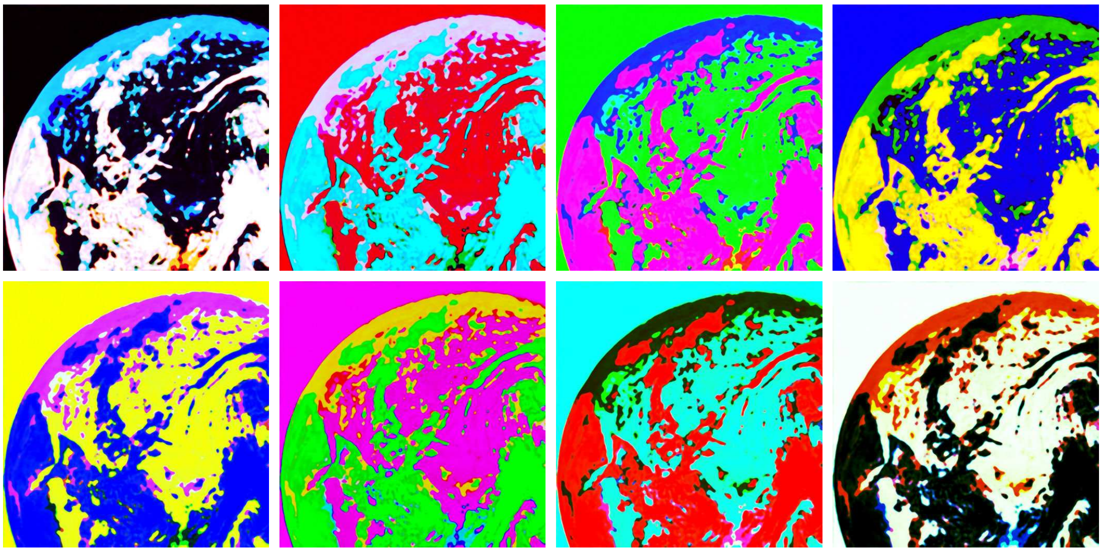


FIGURE 6. Pop art-like images (Earth)

FIGURE 7. Pop art-like images (Mandrill)

FIGURE 8. Pop art-like images (Parrots)

was visually verified through experiments using various images. The experimental results showed that our method can realize three features.

A subject for future study is to expand our method for application to videos and three-dimensional models.

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