Image Watercolorization Based on Color Intensity Alteration

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***Abstract*—This paper presents a watercolor rendering technique that converts photographic images into watercolor painting. An image diffusion and mask filter algorithm are proposed. A heat transfer equation is used as the mage diffusion method and a statistic mask filter is applied to the photographic image processed by the heat transfer equation previously. Experimental results show that better color effect with natural appearance is achieved.**

Keywords: watercolorization; photographic image; diffusion; statistics; mask filter

I. Introduction

Recently the research towards computer graphics becomes more and more popular. Various graphic algorithms have been developed and various graphics-related applications that make the application of graphics more accessible to people's lives have been realized. The functions of mobile phones have even been strengthened by cooperating with computer graphic technology, such as the photographic image can be converted into oil painting or watercolor painting effects. The methods of watercolor effects for photographic images can be mainly classified into physical-based methods [1], [2], [3], stroke-based methods [4], [5], [6]; and filter-based methods [7], [8], [9], [10]. Other watercolor effects including edge darkening, feather-like, hand tremor, granulation, and turbulence have been studied [11]. Wang et al. [11] presented a novel artistic-verisimilitude-driven system for watercolor rendering of images and photographs. Their method can produce watercolor results of artistic verisimilitude better than previous filter-based or physical-based methods. Lu and Chen [12] presented a method organized in two steps: Image abstraction based on the weight-map; and Detail verisimilitude of watercolor features. Verisimilitude method includes color space conversion, boundary region diffusion, morphological smoothing, and adding texture. Liang et al. [13] proposed an algorithm including image graying, edge detection, darkening, pigment diffusion, image expansion to get watercolor stylized images. In this paper, we emphasize the development of image watercolorization based on color intensity alteration to obtain watercolor stylized images with natural watercolor appearance. A simple algorithm including a heat transfer diffusion method and a spatial mask filter based on statistical approach is adopted to process the photographic image for automatically converting photographic image into watercolor paintings. Better natural watercolor appearance can be achieved.

The rest of this paper is organized as follows. Section 2 will introduce our proposed approach including heat transfer diffusion method and a spatial mask filter based on statistical approach. In Section 3, we describe the algorithm of watercolorization. The experimental results will be shown in Section 4. Finally, some discussions and conclusions will be given in Section 5.

II. Our Proposed Approach

The image resolution of a camera can be high such that the adjacent area in a photographic image may have significantly different intensity levels. The intensity level of color edge in a photographic image may change rapidly. However, the adjacent area in a watercolor painting has roughly the same color, and the color will diffuse around. This implies that the adjacent area of a watercolor style photographic image almost has the same intensity level and the intensity of the color edge changes slowly. In order to have a watercolor effect for photographic images, in this paper, a heat equation [2] is used as follows:

$$u^{n+1} = u^n + \Delta t \left[\frac{\partial}{\partial x}\left(K u_x^n\right) + \frac{\partial}{\partial y}\left(K u_y^n\right)\right], \quad (1)$$

where u denotes the temperature, and K can be expressed as

$$K = \mathrm{e}^{-\left(\frac{\|\nabla u\|}{a}\right)^2}. \quad (2)$$

The intensity level of a photographic image can be regarded as the temperature, and the gray-scale distribution is regarded as the object temperature. In heat equation, the high temperature part of the object can let heat transfer to low temperature part. Thus the high-temperature region can be cooled and the temperature of the adjacent region can be raised. Similarly, using the heat transfer equation, the high-intensity area of a photographic image can be decreased, and the intensity of the adjacent area can be increased. A photographic image can be divided into different areas. The boundary of the area can be detected by using conventional edge detection method such as Sobel, Laplacian, or Canny. In this paper Sobel gradient method is used to detect the boundary as follows:

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$$\|\nabla u\| = \sqrt{u_x^2 + u_y^2}\,, \tag{3}$$

where u denotes the intensity value; u_x represents the intensity value in the x direction of the differential; and u_y represents the intensity value in the y direction of the differential.

Our paper has another feature: i.e. the use of a spatial mask filter based on statistical approach. The mask filter algorithm divides the pixel intensities of the image in each mask into 20 levels and computes the highest repetition level. The average value of the intensity of the Red, Green, Blue (RGB) component corresponding to the highest repetition level is calculated and will replace the original values.

III. THE ALGORITHM OF WATERCOLORIZATION

Figure 1 shows the flowchart of our algorithm of watercolorization.

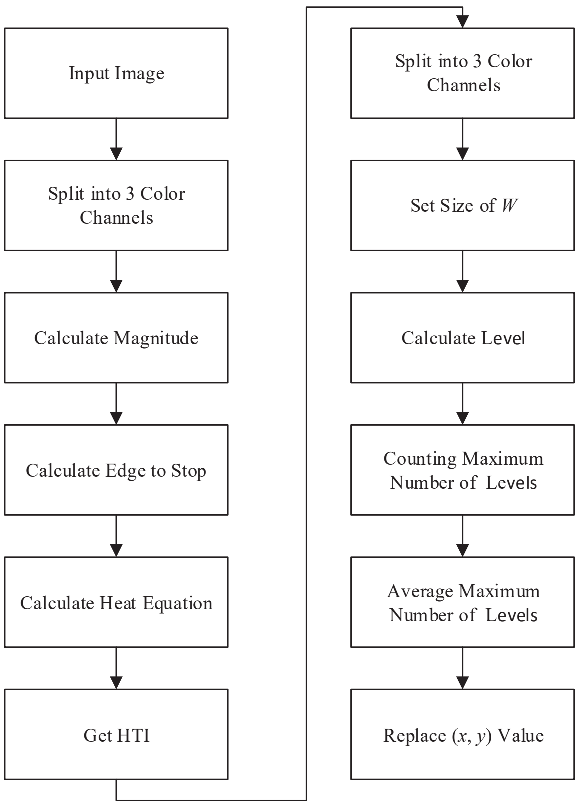

Figure 1. Flowchart of our image processing.

Details of our algorithm of watercolorization are explained as follows:

Step 1: Input an image of size $M \times N$ pixels.

Step 2: Split the image into three color channels: RGB and perform color diffusion with heat transfer equation by implementing Steps 3 to 6 for the three color channels respectively.

Step 3: Set time step and stop time for the heat transfer Equation (1).

Step 4: According to Equation (3), calculate magnitude $\|\nabla u\|$.

Step 5: According to Equation (2), calculate edge to stop K.

Step 6: Solve Heat Equation (1) to get the image u.

Step 7: Repeat Steps 4 to 6 until stop time is reached.

The following steps relate to spatial mask filter based on statistics.

Step 8: Set mask size W, and use Heat Transfer Image $HTI_{(i,\ j)}$, for $W_{(i,\ j)}$ each position $(i,j) \in \{(i,j) | \, i - r \le i \le i + r, j - r \le j \le j + r\}$.

Step 9: Classify each pixel intensity in each mask into 20 levels by summing the intensity levels of the RGB for each pixel, normalize the result, and multiply the result by 20.

$$Level_{(x,y)} = \frac{(R_{(x,y)} + G_{(x,y)} + B_{(x,y)})}{3 \times 255} \times 20. \tag{4}$$

Step 10: Compute the highest repetition level in each mask.

$$mode(Level_{(x,y)}). \tag{5}$$

Step 11: Obtain the average value of the RGB intensity for the pixels corresponding to the highest repetition level respectively and replace the original RGB intensity value respectively.

IV. EXPERIMENTAL RESULTS

We have implemented our new image diffusion and mask filter algorithm and applied it on different scenes in order to evaluate its efficiency.

Figures 2 (a) to 6 (a) show the original image, and Figures 2 (b) to 6 (b) show our result image. We can see that by using our proposed approach, better color effect with natural appearance can be achieved.

(a) Original image.

(b) Our result image.
Figure 2.

(a) Original image.

(b) Our result image.
Figure 3.

(a) Original image.

(b) Our result image.
Figure 4.

(a) Original image.

(b) Our result image.
Figure 5.

(a) Original image.

(b) Our result image.
Figure 6.

V. Conclusion

A heat transfer equation is used as the mage diffusion method, and a statistic mask filter is applied to the photographic image afterwards. Experimental results show that better color effect with natural appearance is achieved.

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