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Research on Simulation Rendering Technology of Watercolor Painting Based on Canny Edge Darkening

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Abstract. Watercolor painting is a branch of traditional painting art, which has a history of more than years of development. Watercolor painting has been widely used and popularized because of its bright colors, transparency, rich expression techniques, strong expressiveness, and simple production tools and materials. The artistic aesthetics of watercolor painting has a wide audience base, which is the premise of the research of watercolor simulation drawing. Edge detection technology is the basis of image measurement, image segmentation, image compression and pattern recognition and other image processing technologies, as well as the technical basis of watercolor digital rendering. Based on the Canny algorithm, this paper proposes a watercolor simulation drawing method based on Canny edge detection. From the experimental results, this method has a good simulation rendering effect.

1. Introduction

Computer art is a new art form that combines science and art. It is a novel and contemporary discipline in the field of computer science. The formation of computer art has had a great impact on the traditional design ideas and design methods of works, and has prompted great changes and updates. For example, the design quality of works has been more guaranteed, the design cycle is shortened, and the design method is improved [1]. It improves the artistic, scientific and feasibility of design. Among them, computer graphics has created a new visual language and new expression style for art, using the form of graphic images to express unspeakable abstract concepts, and the update of graphic image technology has brought a revolution in traditional art. With the continuous development of computer graphics and non-photorealistic graphics, non-photorealistic rendering (NPR) has become a popular research field combining science and art [2]. NPR watercolor painting belongs to an important branch of this field. Researchers at home and abroad are trying to use computers to simulate artists' painting tools and artistic styles in a scientific way, so as to reproduce the artistic characteristics of watercolor painting: that is, the darkening of the edges, the diffusion of pigments, and the flow of water patterns, paper adsorption and texture characteristics, etc [3]. Inspired by the thoughts of predecessors, through the study of simulation methods in the field of non-realism, a new simulation method of watercolor painting was summarized. Based on the Canny algorithm, this paper proposes a watercolor simulation drawing method based on Canny edge detection, which realizes the effective simulation of NPR water-color painting [4].



2. Analysis of Image Edge Detection Technology Based on Canny Theory

2.1. Advantages of Canny algorithm

Canny operator is an edge algorithm with good performance in edge detection [5]. Its advantages mainly include the following three aspects:

- The detection performance is good. The missing detection of the detected edge information is the smallest, the probability of judging non-edge points as edge points is low, and the signal-to-noise ratio obtained is the largest.
- The positioning accuracy is high. The detected edge point is as close as possible to the center of the actual edge.
- The edge response times are the least. To ensure that there is only one pixel response, and false edge response should be maximized suppression.

2.2. Improved Canny algorithm

Although the Canny algorithm performs well in edge detection, it also has shortcomings. Following the study of this algorithm by later generations, it was found that the original Canny algorithm had shortcomings, and many scholars later studied and improved the algorithm. Aiming at the shortcomings of the classic Canny operator's poor adaptability and edge positioning accuracy, and the different performance of edge extraction for different images, this paper improves the gradient magnitude and edge positioning method in the Canny operator to achieve edge extraction [6].

The Canny operator is actually the derivative of the Gaussian function. It is an organic combination of image gradient operation and image Gaussian function smoothing. The first derivative of the Gaussian function does not have rotational symmetry. The algorithm is symmetrical in the edge direction of the image and anti-symmetrical along the gradient direction [7]. This makes the Canny operator in the image edge extraction algorithm, not only can obtain good edge precise positioning, but also have good anti-noise performance.

For an image, the function image $f(x, y)$ is used. The calculation steps of Canny operator are as follows. Assuming that the center edge point of the image is the operator G_n , the two-dimensional Gaussian function is defined as shown in equation (1):

$$G(x, y) = \frac{1}{2\pi\sigma^2} \exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \quad (1)$$

Taking the derivative of x in formula (1), the gradient in the x direction can be obtained as the formula:

$$\frac{\partial G}{\partial x} = kx \exp\left(-\frac{x^2}{2\sigma^2}\right) \exp\left(-\frac{y^2}{2\sigma^2}\right) \quad (2)$$

Taking the derivative of y in formula (1), the gradient in the y direction can be obtained as:

$$\frac{\partial G}{\partial y} = ky \exp\left(-\frac{y^2}{2\sigma^2}\right) \exp\left(-\frac{x^2}{2\sigma^2}\right) \quad (3)$$

Convolve $\frac{\partial G}{\partial x}$ with the function $f(x, y)$ to get the output:

$$E_x = \frac{\partial G}{\partial x} \cdot f(x, y) \quad (4)$$

Convolve $\frac{\partial G}{\partial y}$ with the function $f(x, y)$ to get the output:

$$E_y = \frac{\partial G}{\partial y} \cdot f(x, y) \quad (5)$$

Then the normal vector $\partial(x, y)$ at the point (x, y) of the image is:

$$\partial(x, y) = \arctan \frac{E_y}{E_x} \quad (6)$$

The edge strength $M(x, y)$ at the point (x, y) is:

$$M(x, y) = \sqrt{E_x^2 + E_y^2} \quad (7)$$

According to the definition of Canny algorithm, the convolution of the image $f(x, y)$ and the edge point operator G_n at the image center is the maximum value in the gradient direction at the edge of the image [8].

The process of Canny algorithm for image edge detection is as follows:

- Choose a suitable Gaussian filter to smooth the image to be processed.
- The finite difference of the first-order partial derivative in advanced mathematics is used to calculate the magnitude and direction of the gradient.
- Non-maximum suppression processing is performed on the amplitude value of the gradient obtained in step (2), and the local gradient maximum value and the pixel with the largest gradient at this point are retained. This is used to refine the roof ridge band in the amplitude image.
- The double-threshold algorithm is used for image detection, and the edges are connected to obtain the edges of the image.

The flowchart is shown in Figure 1.

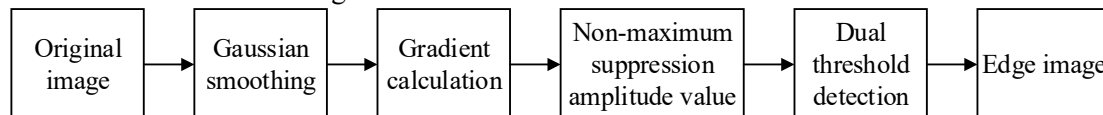


Figure 1. Flow chart of Canny algorithm for edge detection of images

2.3. Canny edge detection algorithm compared with other algorithms

Judging from the renderings, various edge detection algorithms can basically detect relatively accurate edges. The effect contours of Sobel operator and Perwitt operator are clearer, but the noise in the middle of the effect picture is more obvious [9]. For the darkening of the edges of realistic watercolor painting, only the edges in the large color blocks of the image need to be darkened; for the same large color block There is no need to darken the slightly different edges. Therefore, although these two algorithms work well, they are not very suitable for darkening the edges of watercolor paintings. The Robert crossover operator loses part of the detailed information; the Laplace operator detects that the effect is fuzzy and there is more noise. Therefore, these two algorithms are not suitable for the darkening of the edge of watercolor painting [10]. The effect of Canny operator is moderate, that is, it can detect relatively complete edge information, and there is no excessive noise except for edges. Therefore, in this article, the Canny operator is selected as the edge detection algorithm drawn by watercolor.

3. Watercolor simulation drawing process

Edge darkening is a very important part of the watercolor simulation drawing process, which can achieve the characteristic effect that the edge color is darker than the internal color. The simplest idea to achieve this feature effect is to first detect the edge of the image, and then darken the edge by changing the color value of the edge line. This process mainly includes two tasks: one is accurate edge detection, which is the basis for realizing edge darkening; the other is edge darkening processing.



(a) Original image



(b) Robert cross operator edge detection



(c) Sobel operator edge detection



(d) Laplace operator edge detection



(e) Perwitt operator edge detection



(f) Canny operator edge detection

Figure 2. Comparison of edge detection effects of various algorithms

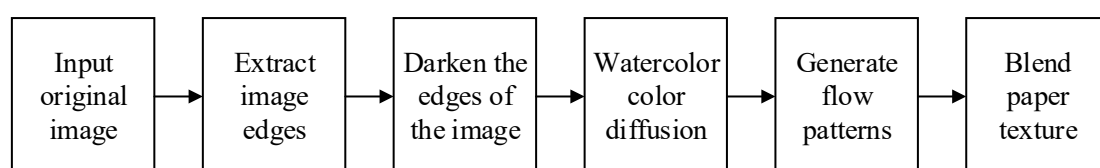


Figure 3. Watercolor simulation drawing process

Basic idea: first, darken the edges of the input original photos. There are two main steps in the processing process: one is to perform edge detection based on multi-scale morphology with scale $n=2$ on the image after binarization to find the edge of the image; the other key step is to correct the image based on the detected edge. The edge information is darkened. Since the color in the RGB model changes from light to dark, it is easy to change the color value of image pixels by performing morphological operations in its spatial model, so it is better to choose the darkening operation in the RGB model. Then perform the pigment diffusion operation on the darkened image. This operation applies the proposed eight-domain weighted average scattering algorithm, and its diffusion effect is better than that in the four-domain. Next, perform flow pattern processing on the image. In order not to damage the color value, this process selects the combination of the designed ring, circle and diamond multi-structural elements in the HSV color model to perform morphological filtering on the image to achieve the processed image has the artistic effect of flowing patterns. Finally, the fusion method is applied to add paper texture to the image, so that the watercolor painting reaches a realistic simulation.

4. Experimental results

Applying the idea of color morphology to the simulation process of non-realistic watercolor painting, operating in different color spaces, so that the color information of watercolor painting is not damaged or lost in any way; the application of multi-scale morphology makes the edge darkening effect more prominent; the combination of multiple structural elements realizes the effect of flowing patterns; adopting the diffusion method in the eight fields and combining the idea of fusion, the diffusion and paper texture effects of watercolor painting are more realistic, close to the style of hand-painted. A large number of experiments have proved the effectiveness of the simulation results of this method. The combination of image processing and morphology is used to achieve the effect of physical simulation, which not only saves time, but also can better reflect the fluidity, diffusion, and adsorption and other characteristics reproduce the most unique artistic style of non-realistic watercolor painting. The final experimental result is shown in Figure 4.

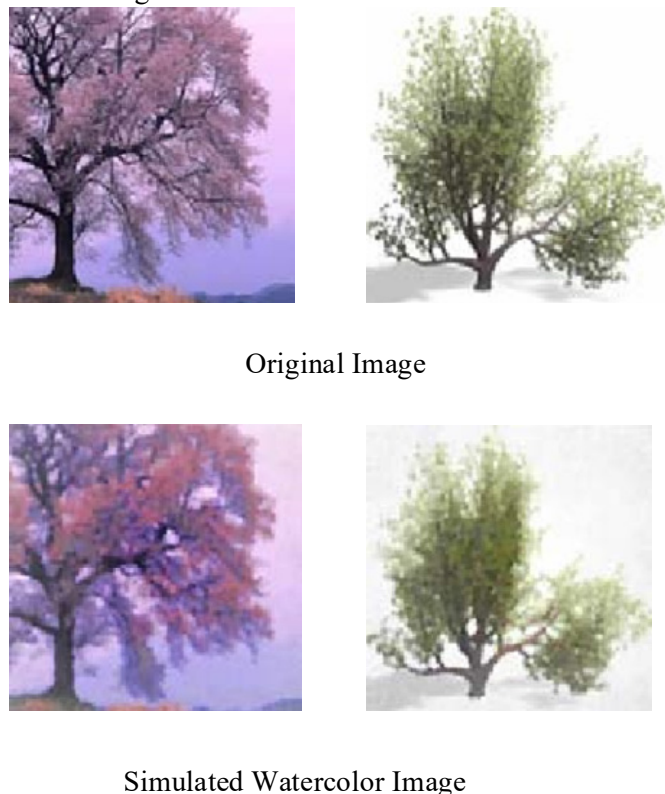


Figure 4. The comparison between the original image and the simulated watercolor painting

5. Conclusion

Through detailed analysis and research on the characteristics and basic drawing techniques of traditional watercolor painting, this paper introduces the methods and goals of non-realistic watercolor painting. This paper proposes a watercolor simulation rendering method based on Canny edge detection and eight-neighbor weighted average diffusion algorithm. The experimental results show that the proposed method has a good rendering effect. From the basic characteristics of artistic creation, both traditional painting and digital painting must abide by the basic laws of artistic creation. Traditional painting provides the source of digital painting, and digital painting can optimize the creation process of traditional painting. At present, as far as the research of watercolor painting simulation technology is concerned, good results have been achieved. Digital watercolor painting is based on the characteristics of traditional watercolor media techniques, covering everything from basic techniques to special techniques, and it is still expanding and improving.

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