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Pencil Drawing Generation Algorithm Based on GMED

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ABSTRACT The automatic generation of pencil drawings from natural images has been a hot spot in the field of nonphotorealistic rendering in recent years and has attracted the attention of many scholars. Aiming at the characteristics of single line drawings generated by the existing pencil drawing algorithm and stiff lines, this paper proposes a new edge generation Gradlent Morphological Edge Detector (GMED) algorithm, which uses the generated edge convolution to generate pencil line drawings, making stylized pictures more natural. First, the gradient map of the input image is extracted according to the feature of the tone rate of change around the line at the boundary. Second, to make up for the shortcomings of too thin and discontinuous lines in the gradient map, morphological operations are performed on the gradient map and convolved to generate a hand-drawn pencil line drawing. Finally, texture filling and tone mapping are performed, and the resulting line drawing is fused to obtain the final pencil drawing effect. Compared with the existing pencil drawing algorithm, the proposed GMED edge generation method is applied to the line drawing generation process to generate a hand-drawn style, fine and concise line drawing, and the texture simulation process is simple and efficient, combined with histogram matching. In the process, a more suitable GML method is used, so that the final pencil drawing not only has natural lines but also colors closer to the input image.

INDEX TERMS Nonphotorealistic rendering, pencil drawing, GMED method, line drawing.

I. INTRODUCTION

Nonphotorealistic rendering (NPR) is a technology that has gradually formed since 1995, and it has become a hot spot in the field of computer graphics [1]. It is widely used in the fields of animation effect generation, artistic illustration outlines, retouching software design and industrial renderings [2]. Unlike photorealistic rendering, which pursues authenticity [3], nonphotorealistic rendering usually transforms natural images into a specific art form, such as pencil painting, oil painting, gouache painting and ink painting. Among them, the generation of pencil drawings based on natural images is the most common form of NPR, and it has also been the focus of research by scholars in recent years.

The process of automatically generating pencil drawings of natural images is very similar to the process of human drawing pencil drawings. It usually includes the following two steps: (1) simulate the lines of the original picture as the outline of the pencil drawn by the artist; (2) simulate the color of the original picture, texture and other details, and merge the tone texture map with the line drawing to obtain a pencil drawing. This article focuses on innovative improvements in the first step and proposes a new edge generation algorithm. This method can make the natural image more close to the original image when it is transformed into a specific art form. It can be used for another hot topic in this field, painting robots, so that robots can draw some scenes in the form of pencil drawings.

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II. RELATED WORK

A. PENCIL DRAWING AUTOMATIC GENERATION TECHNOLOGY

Automatic generation of pencil drawings based on images is one of the most common forms of NPR technology. In recent years, with the promotion of social platforms and retouching software, pencil drawing generation technology has attracted much scientific research and technology worldwide due to its broad application scenarios and economic value. Personnel continues to explore and improve its generation process.

The algorithm of Lu *et al.* [4] is relatively classic. It generates the stroke image S through the gradient map of the input image by convolution. In the process of generating the tone map, the global optimal index model is used to generate the tone, which is combined with the simulated texture. The tone texture map T is output, and finally, the stroke image S is combined with the tone texture map T to obtain the output image, and the pencil drawing effect is natural using this algorithm. On the basis of the algorithm provided by Lu *et al.*, Huang *et al.* [5] simulated pencil drawings with strokes of different lengths and thicknesses at different levels and scales to pursue more details and make all the details in the original image clearer. Part of the process in the literature [6] is similar to the method provided by Lu *et al.* The overall framework is to generate pencil drawings and tone texture maps separately and finally merge the two images to generate colored pencil drawings, but there are innovations in these two steps. Multilevel saliency mapping is used to generate the stroke image, and the color tone is adjusted accordingly. The texture generation process uses the classic linear integration convolution (LIC) algorithm. Reference [7] proposes an improvement to the pencil drawing generation algorithm from the texture generation step. The edge map is extracted by the differential operator, and the texture map is obtained by motion blur processing. By fusing the edge map and the texture map, a sketch map close to the hand-drawn style is generated. The pencil drawing generation method used in the literature [8] is relatively conventional, and it also calculates the texture of small graphics in subregions. First, neon processing and reverse calculation are performed on the original image to obtain the contour map, and then the contour map is divided into several subregions. Finally, the LIC method is used to generate a texture image in each subregion, and the processed subimages are synthesized to obtain an output image.

B. PENCIL DRAWING LINE GENERATION TECHNOLOGY

The generation of pencil-drawn lines can be roughly divided into three methods.

The first method is the line generation method based on the brush model [10]–[12]. In this method, some authors directly select the existing brush style [10], and some authors choose to create a new brush style by themselves [11], [12] and use their selected brush model to follow the original picture. The edge simulates a pencil style line. This method is simple and quick, but the style of the generated image is single, and sometimes even the non-edge area is smeared to make the generated image look messy and unsightly.

The second method sequentially performs neon processing, inversion calculation and grayscale generation on the input image [8], [9]. However, if we carefully observe the characteristics of the lines drawn by pencils, we will find that the lines drawn by pencils are short, thin and intersecting [13]. The lines generated by neon processing do not have such characteristics.

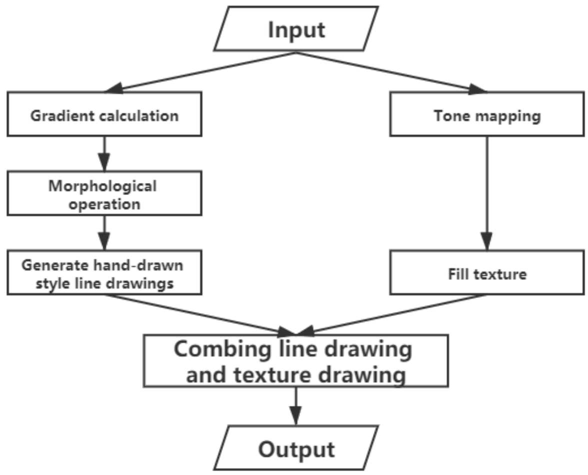


FIGURE 1. Algorithm flow chart of this paper.

The third method directly extracts the edge and use the edge as a pencil drawing. Perhaps these authors have different methods of edge extraction, but most edge extraction algorithms use the classic edge detection operator Sobel operator [14], Robert operator [15], Prewitt operator [16] and Laplace [17], or several of the operators. However, as mentioned above, the edge lines of the image are not the same as the pencil-drawn lines.

According to this situation, this article improves the pencil drawing line generation process, uses the proposed GMED algorithm to extract edges and generates hand-drawn lines based on this.

III. ALGORITHM FLOW

Through reading many studies, it is found that generating stroke outline maps and tone texture maps separately and then combining the two to generate pencil drawings is a relatively classic pencil drawing generation method. This paper uses the same idea to generate pencil drawings. In the process of generating line drawings, the GMED algorithm is used to sequentially extract the gradient map and the morphological expansion of the input image. In the process of generating the tone texture map, the method of histogram matching is used to determine the color, and the selected texture effect directly fills the texture part. Finally, the line drawing and the tone texture map are combined into a pencil drawing effect. The algorithm flow is as figure 1:

IV. PENCIL DRAWING LINE GENERATION BASED ON GMED ALGORITHM

The painter holds the nib and uses quick hand movements to leave some short lines on the drawing paper to form a pencil drawing. This drawing feature makes the line drawn by the pencil a broken arc with a cross at the top. Some scholars simply extract the edge information of the input picture when simulating a pencil drawing line, but it should be understood that the pencil-drawn line is not the same as the edge of the

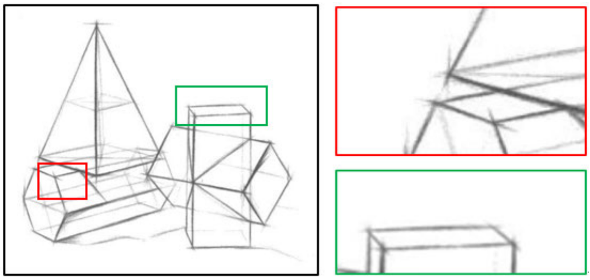


FIGURE 2. Line characteristics of the sketch.

picture. The pencil-drawn line is almost straight and short line segments with the top crossed, as shown in Figure 2, and the edges of the graph are rounded, long line segments without breakpoints.

For this reason, to generate a line drawing with a hand-drawn style, this article improves the existing pencil drawing line generation process. The generation process is as follows: first, extract the edge information of the picture, and then convolve the extracted edge to generate a pencil drawing line drawing.

For the extraction of edge information, the classic edge extraction methods include Canny, Sobel, Prewitt, Laplace, and Robert operators, but they have the disadvantages of weak antinoise ability, disconnected edge lines detected, and excessive unnaturalness. To overcome these shortcomings, this paper proposes a GMED algorithm for edge detection based on gradient maps and morphological operations. The gradient map has the advantages of smooth lines and does not introduce too much noise, but the gradient map has the shortcomings of lines that are too thin or even disconnected. Therefore, after the gradient calculation, the morphological expansion operation is performed to supplement the edge information. Make the extracted edge lines not only continuous and noise-free but also obvious.

A. IMPROVED EDGE EXTRACTION GMED ALGORITHM

The GMED algorithm for edge detection based on the gradient map and morphological operation proposed in this paper. The specific steps are as follows: the first step is to perform gradient operation on the original image to generate a gradient map, and the second step is to perform morphological expansion operation on the initially extracted gradient map to make the edge information richer.

The first step is to perform gradient operations on the original image to generate a gradient map.

The most common method of tonal contrast in photography is to distinguish the subject from the background. The way that the computer determines the subject is different from that of the human eye. People tend to find the object in the center of the picture habitually, but the computer looks for a set of pixels with a large change in tone and regards it as the junction of regional changes. Therefore, to find the boundary of the graph, it is first necessary to find the place with the largest rate of change by calculation. In mathematics, the rate of change is expressed by differentiation, and in computer science, the term "gradient value" is used to specifically express the magnitude of the gray change rate. If the gradient value is large, it means that the grayscale change between two pixels is obvious; if the gradient value is small, it means that there is no obvious color change between adjacent pixels. To suppress the influence of noise on the calculation result, noise reduction is performed on the input image before calculating the gradient value. Then, calculate the gradient value of the point (x, y) in a picture and the surrounding pixels, and the process is as follows:

One-dimensional function derivation formula:

$$\frac{\mathrm{d}f}{\mathrm{d}x} = \lim_{\varepsilon \to 0} \frac{f(x+\varepsilon) - f(x)}{\varepsilon} \tag{1}$$

Since two variables are required to determine the position (x, y) of the pixel in the image, the two-dimensional derivation function should be used to derive the x-direction and y-direction:

$$\begin{aligned} \frac{\partial f(x,y)}{\partial x} &= \lim_{\varepsilon \to 0} \frac{f(x+\varepsilon, y) - f(x,y)}{\varepsilon} \\ \frac{\partial f(x,y)}{\partial y} &= \lim_{\varepsilon \to 0} \frac{f(x, y+\varepsilon) - f(x,y)}{\varepsilon} \end{aligned} \tag{2}$$

Because the interval between adjacent pixels is not infinitely small but a fixed value of 1 so ε in the above formula should be replaced with 1. At this time, the calculation formula of the gradient values g_x and g_y between adjacent pixels of the point (x, y) in the x-direction and the y-direction is:

$$\begin{aligned} g_x &= \frac{\partial f(x,y)}{\partial x} = \frac{f(x+1,y) - f(x,y)}{1} \\ &= f(x+1,y) - f(x,y) \\ g_y &= \frac{\partial f(x,y)}{\partial y} = \frac{f(x,y+1) - f(x,y)}{1} \\ &= f(x,y+1) - f(x,y) \end{aligned} \tag{3}$$

The calculation of the final gradient value of point (x, y) can be expressed by formula (4):

$$g(x,y) = \sqrt{g_x^2 + g_y^2} \tag{4}$$

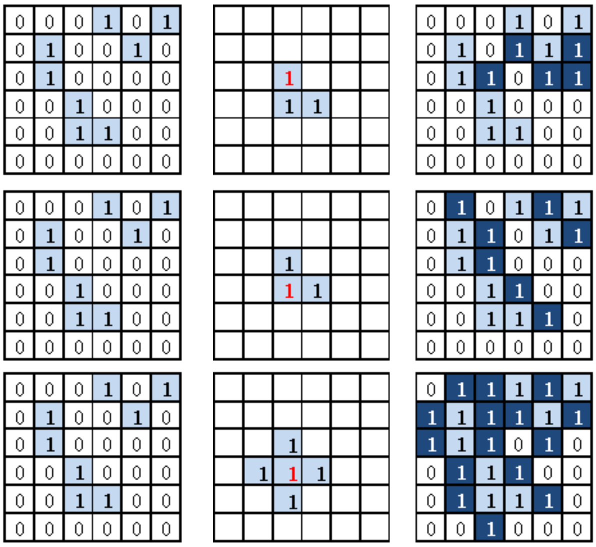
To reduce the number of calculations, many scholars simplified formula (4) as:

$$g(x,y) = |g_x| + |g_y| \tag{5}$$

The author used the above two different formulas to find the gradient value and found that in the calculation result, the gradient value of formula (5) was always slightly lower than that of formula (4), but there was no significant difference between the two formulas in the calculation time. The result is more accurate. This paper uses formula (4) to calculate the gradient value.

The second step is to perform a morphological expansion operation on the initially extracted gradient map to enrich the edge information.

The basic morphological operations include expansion and erosion. The GMED algorithm in this paper mainly uses



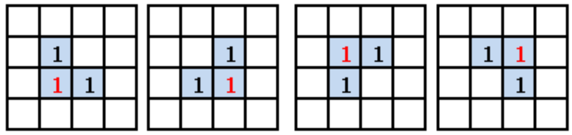
(a) Input picture (b) Structural element (c) After expansion

FIGURE 3. The effect of different structural elements after expansion.

the expansion operation. The principle of expansion uses a set structural element to traverse each pixel in a binary image. Generally, in a binary image, the pixel occupied by the foreground is set to the number "1", and the pixel occupied by the background is set to the number "0". When the center of the structure element (indicated by the bold red "1" in the figure) coincides with the foreground of the binary image, all the pixels covered by the structure element are set to "1". The result of this is to cover the structure element. The black background is replaced with a white foreground. When the area covered by the structural element is all foreground, since "1" is replaced with "1", it is found that the covered pixels do not change. When the area covered by the structural element is all in the foreground, since center "1" of the element does not coincide with center "1" in the foreground, it is found that the covered pixels remain unchanged. Therefore, only when the structure element traverses to the edge area of the foreground will the area covered by it contain both "0" and "1", and when the center of the structure coincides with "1", the covered "0" replaced with "1" means changing the black background pixels to white. After the expansion, the foreground object is visually "expanded", and some broken lines in the foreground object will also be connected after expansion.

Figure 3 shows an example where the input picture has the same foreground but different structural elements after expansion.

From the schematic diagram, it can be found that the shape of the structural element and the position of the center of the structural element have a great influence on the expansion effect. After several changes in the shape of the structural element and the center position of the experimental comparison results, it is found that the structural element contains more than or equal to 4 pixels. The background



(a) Structural element a (b) Structural element b (c) Structural element c (d) (a)Structural element d

FIGURE 4. Examples of different structural elements.

(a) Input image (b) Gradient map (c) Inflated edge map

FIGURE 5. Process diagram of the GMED algorithm.

pixels are replaced with the foreground, and the foreground is deformed. Therefore, the "L"-shaped structural element occupying 3 pixels is selected to expand the generated gradient map. Figure 3 shows that the expansion effect is best when the center of the structural element is located at the geometric center of the structural element. As shown in Figure 4, this article uses structural element a as the structural element in the expansion process, and the subsequent expansion results are also based on this structural element.

This paper proposes that the GMED algorithm for generating edge maps first uses the gradient map to generate edge information and then uses the morphological expansion operation to make the generated gradient lines thicker and connect the breaks. The process is shown in Figure 5. More renderings and comparison diagrams are shown in the experimental results analysis section below.

B. GENERATE PENCIL DRAWING LINE DRAWINGS BASED ON THE EXTRACTED EDGES

To generate sketch lines with a human hand-drawn style, this article draws on the method of generating contour maps in the literature [4]. Reference [4] mainly uses a convolution operation to classify pixels in direction. First, the binary image is calculated in inverse phase, and then the two-dimensional space is divided into eight reference directions at intervals of 22.5° to generate short line segments in eight directions. The discriminant for judging which direction the line segment in the edge map belongs to is:

$$E_i = L_i * E \tag{6}$$

In formula (6), L_i is the short line in the i-th direction, that is, the convolution kernel where $i \in \{1, 2, \ldots\ldots 8\}$. The edge map E is convolved along 8 directions, and the corresponding line segment is defined as E_i. Using the discriminant to combine the line segments, the expression is:

In formula (6), L_i is the short line in the i-th direction, that is, the convolution kernel, where $i \in \{1, 2, \ldots\ldots 8\}$.

(a) Edge map (b) Inverse calculation (c) Convolve into a line map

FIGURE 6. Line drawing process.

Convolve the edge map E along 8 directions, define the line segment of the response as E_i, the direction of the convolution with the largest response is the direction of the point, and use the discriminant to combine the line segments, the expression is:

$$B_i(p) = \begin{cases} E(p) & \arg\min_i \{E_1(p)\} = 1 \\ 1 & \text{otherwise} \end{cases} \tag{7}$$

In formula (7), p represents a pixel. The pixels that respond to all short lines in the i-th direction are reserved and assigned to Bi and output in a combined form. Then, the same operation is performed in the next direction until all Ei are classified. That is, the 8 directions have their corresponding response graphs on the edge graph. At this time, the edge image of the image is only divided into 8 subimages according to the convolution operation. To obtain the unique contour image of the sketch, it is necessary to convolve B_i and L_i again:

$$L = \sum_{i=1}^{8} \left(L_i \bigotimes B_i \right) \tag{8}$$

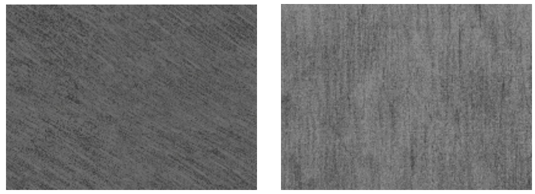
The continuous curves in B_i are convolved along direction i into short, intersecting straight lines and merged to form a pencil drawing line drawing L.

Using this method to generate pencil line drawings, the effect is vivid and natural, and very close to the human hand-drawn style; to facilitate understanding, the process diagram shown in Figure 6 is given.

V. TONE MAPPING, TEXTURE FILLING AND PENCIL DRAWING SYNTHESIS EFFECT

A. TONE MAPPING AND TEXTURE FILLING

The method of directly generating a tone map from a grayscale image is not scientific because the curve peaks of the grayscale image are mostly in the middle, and the pencil-drawn histogram is close to the x-axis in the low brightness value and the middle brightness value range, reaching a certain critical point in the high brightness area. The value shows explosive growth. This kind of distribution occurs because there are few black pixels in the pencil drawing, which causes the histogram to be close to the x-axis at the beginning, and the pixels in the middle brightness are evenly distributed. In addition to the places where they are drawn, there are more white pixels. There is a large gap between the brightness value of the line and the brightness value of the line, causing the curve to rise sharply at a certain critical value in the bright area. Lu *et al.* [4] divided the brightness into three intervals based on the characteristics of the histogram drawn by pencil, followed by the shadow layer, the middle layer, and the highlight layer. Combining the curve trends of the three areas on the histogram, they used the Laplace Si distribution. The uniform distribution and Gaussian distribution represent these three regions, and the expression formula is as follows:



(a) Texture filling style a (b) (a)Texture filling style b

FIGURE 7. Significant area filling texture map and background area filling texture.

$$p_1(r) = \begin{cases} \sigma_a e^{-\frac{1-r}{\sigma_a}} & \text{if} \quad r \le 1 \\ 0 & \text{otherwise} \end{cases} \tag{9}$$

$$p_2(r) = \begin{cases} \frac{1}{u_a - u_b} & \text{if} \quad u_a \le r \le u_b \\ 0 & \text{otherwise} \end{cases} \tag{10}$$

$$p_3(r) = \frac{1}{\sqrt{2\pi\sigma_b}} e^{-\frac{(r-v)^2}{2\sigma_b^2}} \tag{11}$$

In the above formula, $p_1(r)$ $p_2(r)$ and $p_3(r)$ represent the shadow layer, the middle layer and the highlight layer, respectively, and r is the tone value. ua and ub determine the tonal range of the middle layer, which are 105 and 205, respectively, so the shaded layer tones are in the interval [0, 104], and the highlight layer is in the interval [206, 255]. σ_a is set to 9 in formula (9), the proportional parameter σ_b in the Gaussian distribution is set to 11, v is the average value of the shadow layer, and the value of v is found to be 90 after calculation. To map the defined tone mode to the pencil drawing, the formula is as follows:

$$p(r) = \frac{1}{N} \sum_{i=1}^{3} w_i p_i(r) \tag{12}$$

In formula (12), w_i is the weight corresponding to $p_i(r)$, and N is the normalization factor. Next, according to the defined formula, the group mapping law (GML) is used to prescribe the tonal value of the original image to obtain the desired histogram effect.

To generate a pencil drawing texture with a hand-drawn style, this article uses a hand-drawn texture map for filling. Figure 7 shows two different hand-drawn textures for selection. Due to different personal preferences, you can rotate the following image to obtain textures in different directions.

Under normal circumstances, the lighting conditions will affect the sparseness of the texture when the painter draws the pencil. The sparseness of the texture is directly determined by the number of pencil drawing strokes. The greater the

FIGURE 8. The synthesis process of pencil drawing grayscale image.

number of strokes, the darker the texture. Taking this into consideration, this paper defines the formula in the texture simulation process as follows:

$$T = H^{\beta^*} \tag{13}$$

In formula (13), H is the texture effect selected in Fig.19, β^* is the number of smears, and the texture map T drawn by pencil is obtained after rendering H many times. The value of β^* is calculated by formula (4-9):

$$\beta^* = \arg\min \ \ \|\beta \ln \mathrm{H} - \ln \mathrm{J}\|_2^2 + \lambda \|\nabla \beta\|_2^2 \tag{14}$$

The size of J is determined by the formula $H(x)\,\beta^* \approx J(x)$, which means that H is used for β renderings to approximate J.In formula (14), Where the λ weight is 0.2, the above equation can be converted into a standard linear equation and the conjugate gradient method (CG) is used to solve β.

B. PENCIL DRAWING COMPOSITION

To date, the pencil drawing line drawing L and the texture drawing T that are close to the human hand-painted style have been generated. The next step is to merge the line drawing L and the texture drawing T to obtain the final pencil drawing synthesis effect. The synthesis formula is defined as follows:

$$R = L \bullet T \tag{15}$$

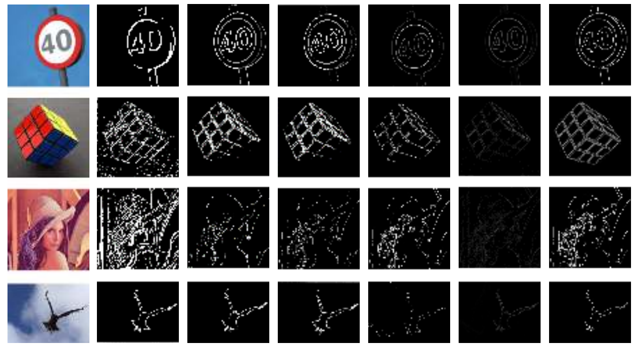
The synthesis effect is as Figure 8:

VI. EXPERIMENT AND ANALYSIS

The hardware environment of this algorithm is a fourth-generation Intel Core i5-4210U dual-core processor (1.7G Hz, turbo frequency up to 2.7G Hz), 32 G memory, 500 GB hard disk, 2 GB independent video memory, a Windows 10 64-bit operating system, and the software environment is MATLAB R2016b version.

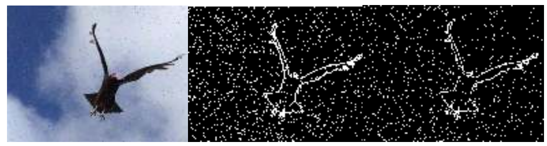
Considering that the innovations of this paper are mainly concentrated in the generation process of pencil drawing line drawings, it mainly explains the effect of the GMED algorithm to extract edges and the influence of different convolution kernel sizes on line drawings.

The BSDS500 dataset is used in this part of edge detection. The 500 pictures contained in this dataset include 100 result pictures, 200 training pictures and 200 test pictures. To expand the capacity of the dataset, this article adds noise to the training images in the BSDS500 dataset and obtains an expanded dataset named EBSDS. The new dataset contains 700 pictures and various complex scenes, which has good guiding significance for verifying the pros and cons of the edge detection model. Without considering adding noise, using the more classic edge detection operator in this dataset



(a) Input picture (b) Sobel (c) Robert (d) Laplace (e) Canny (f) iterature 4 (g) Effect of this article

FIGURE 9. Noise-free edge detection effect.



(a) Input picture (b) Sobel operator (c) Roberts operator

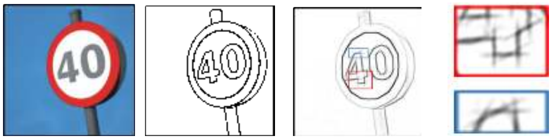
(d) Laplace operator (e) Canny operator (f) GMED algorithm

FIGURE 10. The edge extraction effect of each algorithm after adding salt and pepper noise with a concentration of 0.01.

and the GMED algorithm proposed in this paper in edge extraction, some comparisons are as Figure 9.

Figure 9 shows that the Sobel operator is prone to introduce too much noise in the detection process, and the results of the Robert operator, Laplace operator, and Canny algorithm all lose the lower right corner of the Rubik's cube and the landmark lines of the landmark map. By comparison, it can be found that the GMED edge generation algorithm proposed in this paper has the most comprehensive detection results without introducing additional noise. To further test the antinoise ability of the GMED algorithm, this article uses the training image of the BSDS dataset with 0.01 salt and pepper noise for the experiment and records the edge detection results of the edge calculation with the salt and pepper, as shown in the figure 10. After artificial noise is added, the antinoise ability of the GMED algorithm performs best.

In the process of studying the pencil drawing algorithm, it is found that many scholars directly use the extracted edge as a pencil drawn line, as shown in Figure 11(b). Such a line effect is far from the real pencil drawing. In order to improve the status quo, this paper performs a further operation after extracting the edge information, that is, the edge convolution generates a pencil drawing line with a hand-drawn style. Experiments have shown that such line drawings are closer



(a) Input picture(b) Effect of(c) Effect of this(d) Detail display
other documents article

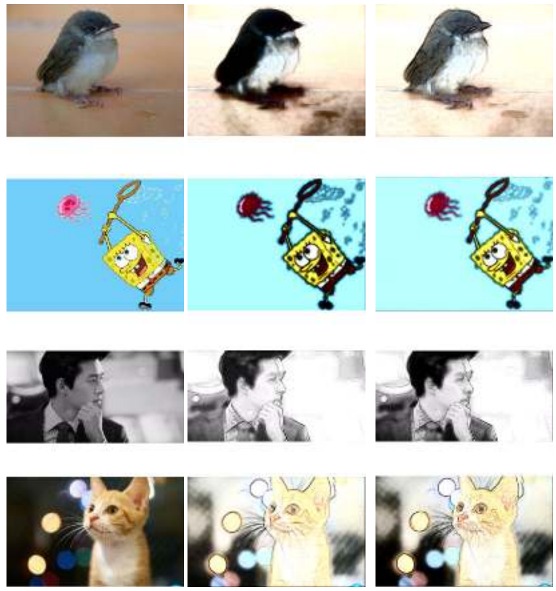
FIGURE 11. **Comparison of line drawings.**

FIGURE 12. **The effect of line drawings with lengths of 7, 9, 11, 13, 15, and 17.**

to real pencil drawings. Like hand-drawn lines, the lines are mostly non-smooth and there are intersections between the lines.

During the experiment in this article, it is found that the length of the line has a more obvious impact on the effect of pencil drawing. Generally, when the length of the line is shorter, the line looks ''rounder'', and it does not look like hand-drawn features. In contrast, the longer the line length, the more obvious the hand-drawn feature. However, it is not as long as possible. Long lines will increase the number of intersections between the lines, and the picture will appear messy. Figure 12 shows the effect of pencil drawing line drawings generated by different line lengths with a 600*400 pixel picture. The line length is the best in the interval [6], [13]. The specific value of the line length can be adjusted according to the size of the picture. When the picture size is small, the smaller value in the interval is taken as the length.

The method of generating pencil drawings in this paper is partially similar to that in [4]: (1) after extracting edges, convolution is performed to generate pencil line drawings, and (2) the histogram matching method is used in the tone mapping process. However, the difference is as follows. (1) Compared with the literature [4], which directly uses the gradient map convolution to generate pencil drawing lines, this article innovatively uses the gradient map combined with the morphological operation GMED algorithm to extract the lines for convolution, and the result shows that the expansion of the lines after the operation is more natural and continuous. (2) In reference [4], the length of the convolution line is set to 1/30 of the side length of the picture. Experiments have found that when the input picture is too large, the generated pencil drawing lines will be very messy. When the input picture is too small, in the generated pencil drawing, the hand-painted effect is not obvious, and this article decided to manually set the line length parameter in the range [6], [13] through many experiments. (3) When performing histogram matching, uses single mapping law (SML), while this article uses GML mapping color. Through experiments, it is found that



(a) Input picture (b) literature 4 effect (c) Text effect

FIGURE 13. **Comparison of the effect of literature [4] with the effect of this article.**

GML is closer to the histogram than SML when performing the prescribed mapping. The specified histogram makes the mapped hue closer to the original image.

Compared with other methods that automatically generate nonrealistic pencil drawings based on natural images, the method in this paper has obvious advantages. Figure 13 is a comparison of the image synthesis effect between the method in this article and the document [4]. Figure 13(c) shows the final effect of the first strokes in this article. Since this article uses a method of combining gradient maps and morphological operations to generate edge information, and sets different line lengths according to the size of the picture, it can be found that the lines in this article are more delicate and coherent in the pencil drawing, while the corresponding lines in Literature 4 are more blurred. At the same time, through the use of GML group mapping rules in the histogram matching process, it can be found that the tones of pencil drawings generated by the algorithm in this paper are closer to the input picture.

The NPR technology simulates the texture, color, line and other style characteristics of different works of art to generate images with the style characteristics and aesthetic quality of the works of art. While improving the efficiency of the generation of works of art, it has narrowed the distance between the public and art, and has been successfully used in animation, heritage protection and other fields. The image-based pencil drawing technology is important in the field of NPR. In the continuous improvement of the image-based pencil drawing technology, this technology can be used in more scenes.

VII. CONCLUSION

This paper proposes a pencil drawing generation method based on GMED edge extraction and makes the following innovations:

1) In the GMED algorithm, for the first time, the gradient map generation and the morphological expansion operation are combined to extract the lines of the input image;
2) Adjust the length of the line according to the size of the input picture so that the generated line has a hand-drawn style and does not make the overall effect of pencil drawing appear chaotic due to the line process;
3) Abandoning the method of using the SML single mapping rule in the traditional tone mapping process, choose to use the GML group mapping rule so that the generated color pencil drawing tone is closer to the input picture.

Experiments show that this method can generate corresponding nonrealistic pencil drawing images for photos of animals, people, scenery, buildings, etc. It has practical significance in art creation, film and television fields, and computer graphics. However, this method also has some shortcomings, including the cumbersome setting of parameters. In the future, efforts will be made to achieve adaptive threshold generation in the generation of pencil drawings.

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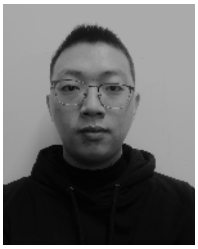

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