Blending Bilaterally Filtered Oil Painting Expression Techniques and Stylistic Rendering of Calligraphy Strokes Combining the Background of Visual Importance

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Abstract. To transform real images into an oil painting style, a bilateral filtering algorithm based on the background of visual importance is proposed. Firstly, the improved bilateral filtering and mathematical morphological operations are combined to a multilayer reference image sequence with a pyramid structure according to the features of oil painting drawing. Subsequently, the stroke layout algorithm based on the visual importance diagram is proposed. The human face, visual focus detection, and other methods are used to detect the influential region. In addition, the starting point of brush drawing, the improvement of direction calculation accuracy, and the enhancement of the image texture boundaries are performed according to the information of these regions to implement the oil painting expression techniques and achieve the highlight effect of the stylistic rendering contents of calligraphy strokes. The experimental results suggest that the bilateral filtering algorithm can be used to achieve relatively good visual effects in the background of visual importance.

Keywords: Non-photorealistic Rendering, Bilateral Filtering, Morphological Operation, Influential Region, Image Vector Field

1. Introduction
In recent years, non-photorealistic rendering (NPR) techniques based on computer algorithms, such as oil painting, watercolor painting, and dot painting, have developed rapidly, and their practical applications have received increasing attention. The general NPR methods are roughly divided into two categories: one is to use physical means to simulate the raw materials of painting; the other is to start from the final effect and refer to the creative process of the real artist to mimic the shape of the strokes. Through optimization algorithms or greedy algorithms Let's implement drawing layer by layer, to implement the generation of an oil painting. The following problems need to be solved in the
process of stylized oil painting based on strokes: 1) How to establish a reference image layer more consistent with the painting process. An important feature of oil painting is the sense of layering of the scene. On each layer, the artist paints with basically the same colors and strokes [1-2]. Hence, each layer model needs to be established by a specific method according to the input image, and these models need to gradually represent the details of the image from coarse to fine. 2) Establish an effective oil brush painting model. In the process of realistic drawing, the artist uses the pen's ink on the canvas to describe the scene, and the visual and psychological information to be expressed are expounded. The main idea of the classical algorithm for stylized rendering of oil painting based on strokes is to build a multilayer reference image of a Gaussian pyramid from a static input map, and then use filter functions such as Sobel to obtain the gradient information of the image in each layer, thereby establishing the starting point and direction of the brush, and then gradually paint the canvas from coarse to exquisite. The Gaussian filter kernel function is used to process the reference image sequence [3] to obtain a reference layer sequence consistent with the original image size. For the starting point of the stroke, firstly, the correspondence is established with the radius of the stroke. Subsequently, the pixel error sum of the corresponding reference image in the region and the current canvas in each grid are counted [4]. If the value is greater than a threshold given by the user, define that a stroke needs to be established in the grid region. The starting point, the center of the starting point of the stroke is the pixel point with the largest pixel value error in the grid area; the direction of the stroke is mainly determined based on the gradient information at the starting point of the stroke [5]. Since then, to improve the surface realism of oil painting, some scholars have developed oil painting based on the lighting model based on the above work. The main idea of this work is to first calculate the height field information from the image, and then use lighting models such as Phong to integrate the factors into the calculation of the stroke drawing algorithm. In this way, it can plot highlight regions and shadow regions, thereby producing a specific lighting visual effect. For stroke models, factors such as edge transparency are also introduced to try to draw the stroke effect closer to the painter. Hand-drawn stroke drawing style [6].

This article improves the traditional stroke-based oil painting algorithm, which is different from the global unified blur effect produced by the traditional Gaussian pyramid model. In this paper, the bilateral filtering in the background of visual importance is combined with the bilateral filtering with the full consideration of the anisotropy on the texture. Mathematical morphological operations that generate locally uniform color information blocks to build a pyramid reference image sequence, and strengthen constraints on stroke boundaries in oil painting expression techniques and calligraphy strokes. Stylistic rendering methods based on human visually sensitive regions; while detecting strokes, the threshold and stroke direction are further processed on the calculation of the most delicate layer.

2. Bilateral filtering algorithm in the background of visual importance

Figure 1 shows that in the background of visual importance proposed in this paper, bilateral filtering has been improved in the following aspects: 1) On the pyramid reference image sequence, a bilateral filtering process that fully considers image spatial texture and color detail information is used, and morphology is used. The operation integrates large pieces of image information to adapt to the drawing of corresponding strokes; 2) The calculation of the starting point and direction of the strokes is improved based on the importance distribution in the region of image importance, and stroke
boundaries are constrained using texture boundaries.

Figure 1. Bilateral filtering process in the background of visual importance

2.1. Pyramid reference sequence generated by bilateral filtering and morphological operation

The principle of establishing the pyramid reference sequence is to not only make the layers too trivial, thereby highlighting the effect of oil painting, but also to maintain the content information of the image to ensure accuracy. Because the Gaussian filter uses a globally unified kernel function, the filtering effect produced is generally fuzzy, and it cannot provide good discrimination on the pyramid for texture boundary information and expected hierarchical high-frequency details. Also, Gaussian filtering down samples the image by rejecting even rows and columns and then up sampling according to the bilinear interpolation method to obtain a reference layer that is the same size as the original image. The up-sampling mentioned above is also prone to loss of information, forming an image.

The effect of the bilateral filtering algorithm can ultimately maintain the main texture and boundary information of the image, and at the same time, it can adaptively smooth out the small data in the block.

Assuming that \( \hat{x} \) is a certain pixel to be processed, \( x \) is a pixel point in the neighboring pixel set \( \Omega \), and \( p(x) \) is a pixel value of the point. The definition of the kernel function of the bilateral filter is shown in equation (1):

\[
B(\hat{x}, \sigma_d, \sigma_r) = \frac{\sum_{x \in \Omega} \frac{1}{\sqrt{\pi} \sigma_d} e^{-\frac{(x - \hat{x})^2}{2 \sigma_d^2}} \cdot \omega(x, \hat{x}) \cdot p(x)}{\sum_{x \in \Omega} \frac{1}{\sqrt{\pi} \sigma_d} e^{-\frac{(x - \hat{x})^2}{2 \sigma_d^2}} \cdot \omega(x, \hat{x})}
\]

The denominator part is the normalization operation of the weighting coefficient. The definition of the weighting coefficient is shown in equation (2):
\[
\omega(x, x, \sigma_r) = e^{-\frac{1}{2} \left[ \frac{p(x) - \hat{p}(x)}{\sigma_r} \right]^2}
\]  \hspace{1cm} (2)

Where \( \sigma_r \) and \( \sigma_d \) represent the intensity factor and the space factor respectively representing the color component. In fact, when \( \sigma_r \rightarrow \infty \), \( \omega(x, x, \sigma_r) \rightarrow 1 \), and the filter is completely degraded to a Gaussian filter.

To facilitate the generation of a wide range of visually uniform color blocks in the image, and thus to better generate smooth processing of strokes, this paper uses a mathematical morphological close-and-open operation to process bilaterally filtered images. For the integration of image-rich detailed information blocks, this paper adopts a mathematical morphological processing method. In morphology, corrosion can eliminate boundary points and shrink the boundary to the inside, so small and meaningless pixel regions can be eliminated. Swelling is to merge all obtrusive points or high-frequency points in contact with the pixel block into the object, so that the boundary of the entire block expands outward, so the purpose of filling the void integration of the pixel block can be achieved. This article combines the two, and uses the open operation (corrosion first and then expansion) to eliminate small clumps, separate pixel blocks at slender points, and smooth the boundaries of larger blocks; the closed operation (expands first and then erodes) can fill the small holes in the color blocks, the connection of adjacent blocks and the smoothing of their boundaries, and the combination of these two operations will not significantly change the spatial features of the color blocks.

In Figure 2, the multi-layer reference image generation process based on bilateral filtering and morphological operation algorithms is described. In the process of bilateral filtering the image, the values of \( \sigma_r \) and \( \sigma_d \) in equation (1) (2) become larger as the reference layer number increases (that is, gradually discard the texture details), followed by the filtered image Morphological operation after closing and then opening to form a reference layer for each layer.

\[\text{Figure 2. Multi-layer reference image generation process for bilateral filtering and morphological operation}\]
2.2. Constraint of image influential region

From the perspective of human visual sense, there are often some sensitive regions in the image information, such as the human face and the golden section in the close-up photography composition. After the oil painting effect is created, if the stylistic rendering in these regions is rough, the viewing effect will be greatly damaged, so certain boundary constraints need to be made according to these influential regions. In this paper, the intensity of the boundary extraction of each region is determined according to the importance distribution of the image, and the strokes are constrained by the extracted boundaries.

1) Face area. First, the face detection technology was used to search the circular region of the face. As a hot topic in computer vision, the algorithms for face detection research have been developed very well. This paper uses face detection technology for face detection. Generally speaking, people are particularly sensitive to the eyes and their surroundings, and the eyes are usually in the upper half of the circular area. Also, while enhancing the circular area, it is necessary to consider the asymptotic effect of the roughness of the surrounding area. Based on the above analysis, this article makes the following importance parameter settings for the circular region and its surroundings detected by the face: the upper semi-circular region of the face is uniformly set with the importance parameter \( \alpha_1 \), and the lower half region is set to \( \alpha_2 \). At the same time, at each point outside the circle, the important parameter is gradually reduced in a manner proportional to the distance from the pixel point to the center of the circle. When reaching a pixel point with a radius twice as large as the center point, the important parameter of the point is 0.

2) Focus of near and far shots. In the distant view composition view, the visual focus is generally at the lower position of the image center, so the importance detection similar to the above method is performed in this area. Close shots are usually at the left and right two golden section points in the upper half of the image. The close shot focus detection method is the same as above.

After the influential region is obtained based on the above method, it is necessary to perform boundary extraction on the image. There are many kinds of image boundary extraction algorithms, such as Sobel algorithm and Canny algorithm, etc. This paper uses the boundary extraction algorithm proposed. This algorithm performs preprocessing based on bilateral filtering, and then obtains a smoother and more accurate boundary according to a Gaussian Difference (DoG) operation. To ensure that the degree of detail extraction of the boundary is proportional to the regional importance parameter \( \alpha \), it is defined as equation (3):

\[
D(\hat{x}, \sigma_v, \alpha, \tau, \varphi) = \begin{cases} 
1, & \text{if } \left( \left| S(\hat{x}, \sigma_v) - \alpha \circ \tau \circ S(\hat{x}, 1.3 \circ \sigma_v) \right| \right) > 0 \\
1 + \tan h \left( \varphi \circ \left( S(\hat{x}, \sigma_v) - \alpha \circ \tau \circ S(\hat{x}, 1.3 \circ \sigma_v) \right) \right), & \text{otherwise}
\end{cases}
\]  

(3)

The Gaussian fuzzy function is shown in equation (4):

\[
S(\hat{x}, \sigma_v) = \frac{1}{2 \circ \pi \circ \sigma_v} \int f(x) \circ e^{-\frac{(x-x)^2}{2\sigma_v^2}} dx
\]  

(4)
In equation (3), α is the distribution factor of image influential region; σ in equations (3) and (4) is a spatial scale, τ is a boundary detection sensitivity factor, and φ is a boundary brightness factor.

After the image boundary is obtained from the above method, the specific method for the boundary constraint operation is: during the stroke drawing process, when the stroke center of a certain stroke crosses on the boundary obtained by DoG, the spanned part cannot be drawn, and the stroke ends early.

3. Experimental results
The experiments in this paper use ordinary JPEG compressed pictures as input, and use the traditional stroke-based oil painting drawing algorithm and the software generated by the improved algorithm for stylistic rendering to compare the improvement of the enhanced algorithm on the drawing effect.

Compared with the traditional algorithm, the algorithm in this paper can produce a consistent blur effect for large image blocks, and this blur meets the classification of visual perception. At the same time, the rough texture on the image can be more clearly retained under the overall blur. The improvements in the above two aspects benefit from the introduction of bilateral filtering on the reference layer. At the same time, the secondary perceptual texture details in the large pixel block can be effectively removed, and some more sensitive small pixel blocks (such as the region on the arm) can be preserved entirely. Such processing results and the theory of mathematical morphology The analysis is consistent.

Figure 3. Stylistic rendering results of image oil painting expression techniques and calligraphy strokes

Figure 3 shows that the oil painting expression techniques and calligraphy strokes stylistic rendering results on the border based on the algorithm are smoother and more natural. At the same time, due to the improvement of the finest layer, the drawing on the face is also more delicate and realistic. Details in the influential regions such as faces are more accurate. Hence, the improved stroke direction processing can get closer to the texture direction. This is due to the improvement of the
overall stroke direction, which promotes the surrounding region strokes to better follow the main boundary, and also because of the improvement of the reference image generation algorithm and Improved visual effects caused by constraints on the borders of strokes in the influential region.

4. Conclusions
In this paper, the bilateral filtering and mathematical morphology operations are used to establish a pyramid reference image sequence. The experimental results show that the new reference image sequence has a texture direction and clear boundaries easier to draw with strokes. Meanwhile, as stroke starting threshold adjustment is adjusted in the proposed algorithm, the improvement of direction accuracy and the enhancement of boundary constraints based on the sensitive coefficients on the finest layers of the above stylistic rendering of oil paintings in human visual sensitive regions, the contents of the oil paintings generated based on this algorithm have a distinct and clear focus, with a more outstanding oil painting effect.

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