THE SYNTHESIS OF ROCK TEXTURES IN CHINESE LANDSCAPE PAINTING

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Abstract

In Chinese Landscape Painting, textures of rocks present the orientation of mountains and build atmosphere of paintings. Lots of landscape painting skills are concomitant according to varied rocks. By experience, people decide which skill to be used to generate the style they expect. This paper proposes a method to synthesize rock textures in Chinese Landscape Painting. The major advantage of our work is to save the time of trying error and synthesizes painting styles of rocks quickly. Users just specify the rock contour, texture strokes areas, and stroke parameters, then our system will underwrite the whole painting process. People do not need to be familiar with painting skills, and they could paint out various styles of rocks in Chinese Landscape Painting.

Keywords

Non-Photorealistic Rendering(NPR), Chinese Landscape Painting, TS'UN, Hemp-Fiber Texture Strokes.

1. Introduction

In Computer Graphics, a lot of researches focused on obtaining photorealistic images. Researchers tried to make their synthesis or simulations as realistic as possible. However, for effects of vision or other particular reasons, the photorealism sometimes is not the best way to express emotion and aroma. That is why photographs can not completely replace paintings. Accordingly, techniques of non-photorealistic rendering are more appreciated recently. Researchers began to study how to let a photograph or a photorealistic image looked like an art painting.

Up to now, most researches [3,7,10,11] of non-photorealistic rendering focus on the West painting. Lots of painting algorithms are built to convert a photorealistic image into an art form such as oil painting, watercolor, and et al. The usual way to create such a painting style is by applying various particular masks [3,10] or placing patterns [7,11] defined by users. These methods present good solutions in cases of the West painting. But, for Chinese Ink Painting, these approaches are not appropriate. Generally, West painting asks for more precision but Chinese Ink Painting is more abstract. On the other hand, strokes in Chinese Ink Painting are based on Chinese brushwork in many aspects. It is not only works of color filling or pattern placing but also describing details with kinds of brush sizes and techniques.

This paper proposes a method to synthesize rock textures in Chinese Landscape Painting. According to rock textures, we conduct some types of painting models that are frequently used by painters. According to these models and structures, people just define contour of rocks and texture strokes areas sketchily. Then our system will take over the whole painting process.

1.1 Previous work

Depending on the knack of painting, researches of NPR [3,7,9,10,11,15] focus on different point. For example, a proper brush model is important while simulating Chinese Ink Painting, but the crucial point of oil painting is color distribution. The researches of NPR are classified into three categories. The first category is to transform photorealistic images to non-photorealistic images [3,7,10,11]. By mapping various user-defined textures or patterns to an image, different styles of the non-photorealistic image are generated. The second category analyzes information of images, such as illumination or lighting direction, to generate various sketch effects [9,15]. Image generated from this category are usually monochrome, and stereo is present via distribution and density of sketch strokes. The third category is focused on brush and painting model [1,4,12,16,17]. Researches of this category are usually applied at the art which emphasizes strokes and ink effects, especially in the oriental painting. Since we generate texture strokes and paint them with a proper brush model, this category is closely related to our work.

While simulating Chinese Ink Painting or Japanese Sumi-e, a proper brush model to synthesize realistic strokes is prerequisite. Strassmann [12] proposed a basic brush model of ink painting. He defined a one-dimensional array as the painting brush, and elements in the array are taken as bristles. Besides, Strassmann also defined several parameters to simulate painting styles. For example, the ink quantity is used to simulate dry brush effect and the stroke width is controlled by brush size.

1.2 Overview

The rest of this paper is organized as follows. In section 2, we introduce the property of Chinese landscape painting. Details of the texture stroke area of rocks are described in section 3, and the policy of hemp-fiber texture strokes is introduced in section 4. For synthesizing effects of Chinese Ink Painting, we introduce an applicable brush stroke model in section 5. In section 6, we demonstrate results generated by our system. Finally, conclusions and future works are given in section 7.

2. Chinese Landscape Painting

Chinese Landscape Painting is an important rubric in Chinese Ink Painting. In Chinese Landscape Painting, rocks are major objects because it possesses the aroma of paintings. The artists use the character TS'UN(皴), also meaning wrinkles, to stand for texture strokes applied to rocks formations. Over the centuries, the masters developed various types of TS'UN technique, which form the essential foundation of any artist's training. Two major types of TS'UN techniques exit : Hemp-Fiber Strokes(披麻皴) and Axe-cut Strokes(斧劈皴). A slightly sinuous and perhaps broken line, the hemp-fiber stroke is used for describing the gentle slopes of rock formations; The Axe-cut stroke is most useful for depicting hard, rocky surfaces.

Long hemp-fiber strokes express relatively smooth surface. Short hemp-fiber strokes provide more wrinkles. Entangled hemp-fiber strokes tend intercept on another from different directions, expressing roughness of the surface and a feeling of casualness in the brush application. The great Southern School master Tung Yuan(董源 907-960 AD) fist developed the short hemp-fiber strokes. These were given variations and generally favored by the literati painters, who dominated mainstream Chinese landscape painting beginning with the emergence of the Four Master of the Yuan Dynasty. The most important of the four Masters is Huang Gung-wang(黃公望 1269-1354 AD), who practiced the strokes in a loose, calligraphic manner.

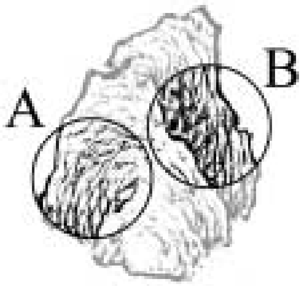


Figure 1. A rock painted with the Hemp-Fiber Stroke.

Conventionally, we apply particular texture strokes according to the characteristic of painted rocks. So there will not be too many kinds of TS'UN on a painted rock sumultaneous. In general, we apply only one kind of TS'UN when we paint a rock. It is intelligible because a rock is composed of a single stuff. Figure 1 shows a rock painted only with Hemp-Fiber Stroke but texture strokes are varied in different areas of this rock.

This paper focused on Hemp-Fiber Stroke. Because it is the major stroke in Chinese Landscape Painting, there are still lots of other strokes should be integrated in our system. Since the concept of texture strokes area is highly capable, it will not be too hard to integrate other strokes. The property of Chinese landscape painting with hemp-fiber stroke is as follows : (1)An artist begins to visualize a land formation with external contours, which define the overall shape. Internal contour, added to suggest folds on the slopes, reveal the position and direction of the ridge and determine its volume. (2)After the internal contours are defined, the next step is to apply texture strokes in the area. (3)Using Hemp-Fiber Stroke to stand for smooth land surface. (4)Finally, the brush will move along the path of stroke and deposit ink on the canvas.

3. Texture Stroke Area

When we paint rocks in Chinese Landscape Painting, we usually draw the rock contour before applying texture strokes. In the contour painting process, the painting order of silhouette edges is from the farthest edge to the nearest one because nearer edges may occlude farther edges. We construct silhouette edges from far to near progressively. As shown in Figure 2, the stroke which has higher order (smaller label) implies that it is farther from view point relatively and will be drawn earlier.

For constructing the rock contour, we specify control points of contour strokes orderly. Then we will detect whether some strokes cross over others. Once it happened, the lower-order stroke will clip the higher-order one and the higher-order stroke will be re-constructed. Figure 3(a,b) compares the rock contours before and after clipping and Figure 3(c) shows the rock contour after applying Cardinal Spline. After constructing rock contour, the next step is to specify texture strokes areas. Rock contour specified by user is an important reference when we specify texture strokes areas.

Figure 2. The silhouette edge with higher order (smaller label) is farther to the view point.

(a) (b) (c)

Figure 3. (a) Rock contour before clipping. (b) after clipping. (c)Cardinal Spline applied at the cut contour

3.1 Definition of Area

The texture stroke area is a region, in which only one style of rock textures is applied. Besides, a texture stroke area is equipped a *painting mesh*, which consists of 10×10 grids, to control the orientation and distribution of texture strokes. As shown in Figure 4, a texture stroke area encloses a region, but the texture is actually applied inside the rock contour which is gray color. Coordinates of each grid point of a *painting mesh* is mapped to the region that we actually apply textures. In other words, a *painting mesh* subdivides the actually texture strokes painted region into 10×10 sub-regions. This mechanism helps us to control the style and distribution of each stroke.

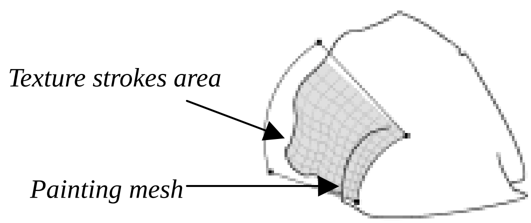


Figure 4 The texture strokes area painting mesh.

3.2 Contour Structures in Areas

When we construct a texture strokes area, some edges of rock contour will be enclosed in it. These enclosed edges always form some particular structures. By conducting and recognizing these structures, our system adapts the *painting mesh* to fit the actual painting region. Figure 5 depicts these basic structures. Since we reduce homogenous cases to be one case by rotation and symmetry, the number of representative contour structures is only 3.

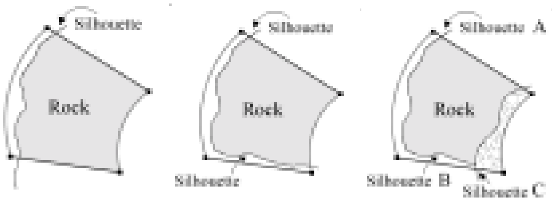


Figure 5 Three basic contour structures.

Consider Figure 5, each case represent one situation while adapting the *painting mesh*. We describe them as follows:

Case 1: Only one silhouette edge is inside the texture stroke area. While adapting the *painting mesh*, we map an arc of the texture strokes area to the silhouette.

Case 2: Two silhouette edges are enclosed in the texture stroke area, and they will be mapped by an arc and a line segment of the texture stroke area respectively.

Case 3: Although three silhouette edges are enclosed, silhouette C can not be mapped by any arc or line segment. Consider Figure 6. When we observed from some view point, there could be several rock faces overlapped together. The face closer to the view point is the front face, and the face farther from the view point is the rearward face. In Case 3, rock silhouette C divides rock faces into the front face and the rearward face, which are gray and dissolve respectively. Since an arc and a line segment should be mapped to edges A and B, which are silhouettes of the rearward face, texture strokes should be applied at the rearward face. It implies that the orientation of textures should follow the silhouette edges of the rearward face. So, silhouette C can not be mapped by any arc or line segments of the texture stroke area.

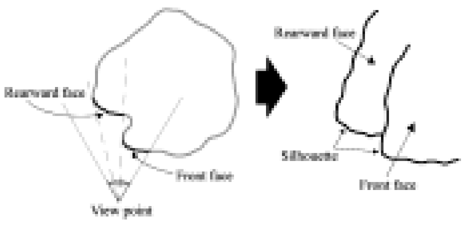


Figure 6. The front face and the rearward face.

Conduction of contour structures in texture stroke areas helps us to adapt the *painting mesh* precisely. Although contour structures enclosed in a texture stroke area are different case by case, they are never out of this domain. In section 3.3.3, we introduce the method, which applies knowledge of basic contour structures in a texture stroke area, to adapt the *painting mesh*.

3.3 Painting mesh adaption

The purpose of adapting a *painting mesh* is to fit the mesh vertices to the region of rock where we actually apply textures. This process could be thought as making a *painting mesh* to wrap up the rock contour. It takes three steps as follows:

Step 1: Corner vertices adaption.

Step 2: Boundary vertices adaption.

Step 3: Internal vertices adaption.

In step 1, we apply "bullet shooting" process to adapt corner vertices. Consider Figure 7. Imagine that rock contour edges are "walls", and we shoot a "bullet" from a corner vertex to its target vertex. If the bullet is obstructed by some contour edge, we calculate the hit point on rock contour, and judge whether the source corner vertex should be re-positioned on it.

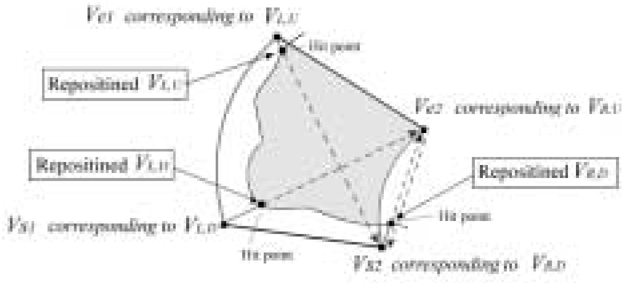
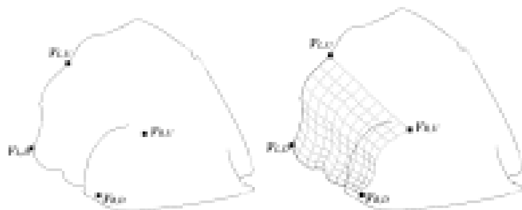
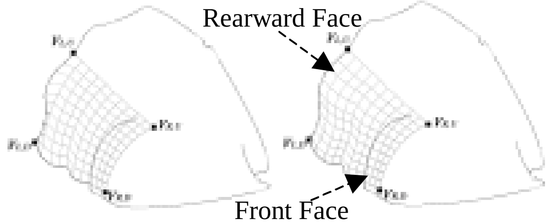


Figure 7. The process of bullet shooting from source vertices to target vertices.

Since the painting mesh is a of 10×10 grid, in step 2, we insert 9 points as the boundary vertices between two corner vertices of the painting mesh. If two neighboring corner vertices have no path to connect each other, we inserted points between them by linear interpolation. But, if there is a path between two neighboring corner vertices, two rules should be followed while inserting points on the path: (A) Features of rock contour should be held. (B) Interpolated points should be uniformly distributed on the path**.**



(a) The positions of corner points after step 1. (b) The painting mesh consisting of left side.



(c) The painting mesh consisting of right side. (d) The painting mesh after blending (b) and (c)

Figure 8. The process of internal vertices adaption.

In step 3, we use vector operation to obtain the internal vertices. Since the painting mesh is subdivided into 10×10 grid uniformly, the blending function is linear. Figure 8 shows the process of step 3. After step 3, a painting mesh wraps up the actual-painting region tightly. This mesh maintains rock contour features and uniformly divides the actually-painted region into 10×10 sub-regions.

While applying textures, strokes are generated in the mesh.

3.4 Mask

As shown in Figure 6, for an arbitrary rock, part of its surface may be concave. When observed from particular views, there could have several convex parts overlapped together. The convex parts closer to the view point will occlude the farther ones. Since the silhouette of rocks is free-form curve, the texture stroke area could covers two or more overlapped convex parts when specified interactively by users. But, the stroke patterns of these overlapped parts are usually different. In order to prevent the stroke pattern of one overlapped part painting over the other part, we define a mask to prevent those strokes passing through the silhouette. While applying it, people should define the boundary conditions and a seed point in the region. Then the seed point will "grow up" until it fills up the region described by the boundary conditions. Consider Figure 9(a), since the mask should be in the texture stroke area, boundary of the texture stroke area is a boundary condition. Since the contour edge C is the silhouette of the two overlapped parts, it is also a boundary condition. The selection of seed point is quite free. Any point in the region can be selected as the seed point. Consider Figure 9(b), we pick a point **b** on silhouette edge C properly and obtain the mid point $\mathbf{m_b}$ between V_{s2} and **b**. Since $\mathbf{m_b}$ is located in the region , we could take it as the seed point.

The painting mask is saved as a bitmap image. Pixel color in the mask region is false and pixel color out the mask region is true. While depositing ink on canvas pixels, the ink color should multiply the Boolean color of the corresponding pixel in the mask image. So, ink will not be deposited on pixels which are masked.

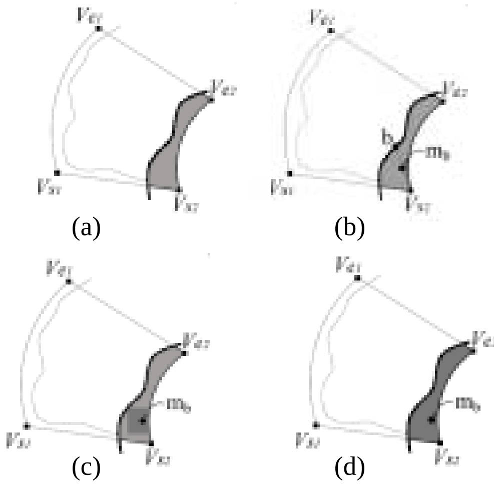


Figure 9. The process of generating mask.

(a) Build the boundary conditions. In this case, the black bold strokes are the boundary.
(b) Obtain the seed point $\mathbf{m_b}$ in the region.
(c) Start the region growing process.
(d) The mask, which is colored dark gray, is established.

4. Hemp-Fiber Texture Strokes

In our approach, we parameterize these stroke characteristics, and generate various rock textures with different combinations of parameter values. We use the knot and exclusive region, which will be described in Section 4.1, to control the distribution and density of strokes. The rest sections, we introduce three parameters: length, crossing angles, and perturbation. Stroke styles are presented with these three parameters. With different combinations of spatial and style parameters, users could generate various hemp-fiber texture strokes.

4.1 Distribution and Density

In our system, we take the distribution and density of strokes as spatial parameters. They present illumination effects, which make the painted rock stereo. Dense strokes are applied on dark rock surfaces and sparse strokes are applied on bright rock surfaces. We use knot and exclusive region to control both of them. Consider Figure 10. A knot could generate one or two strokes. If two strokes are generated by a knot, they cross each other at the knot. Control points are specified at each square overstretched by the strokes in the painting mesh. A set of knots are placed in the painting mesh, and they generate strokes to mold rock textures. So, distribution of knots determines the distribution of strokes. For controlling knot distribution and density, exclusive region is involved. Consider Figure 11, each knot has its own exclusive region. Once a knot is placed in a painting mesh, its exclusive region is set up at the same time. Exclusive region is an ellipse with short axis A, long axis B, and center S (knot). No any knot can be placed inside other exclusive regions.

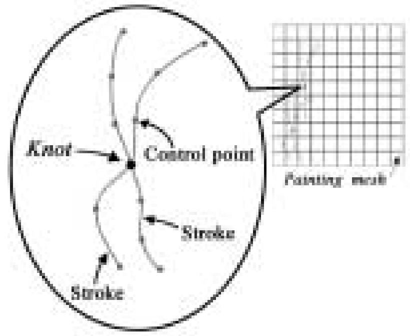


Figure 10. Two strokes generated by a knot

Process of placing *knots* in the *painting mesh* is like region growing. Consider Figure 11. It starts from a *knot* which is randomly placed in the *painting mesh*. After set up its *exclusive region*, the *knot* litters three children on the boundary of its *exclusive region*. Each child checks whether it is inside the other *exclusive region*. If not, this child set up its *exclusive region* and litters three children as its parent. Otherwise, it is removed because no *knot* could be placed in any *exclusive region*. This process executes repeatedly until the whole *painting mesh* is occupied by *exclusive regions*. Since *knots* can not be placed inside others *exclusive region*, strokes will not be unexpectedly crowded. Otherwise, since *knots* are placed on the boundary of the *exclusive region*, texture strokes will not be too sparse. Figure 12 shows the process of placing *knots* in the *painting mesh*.

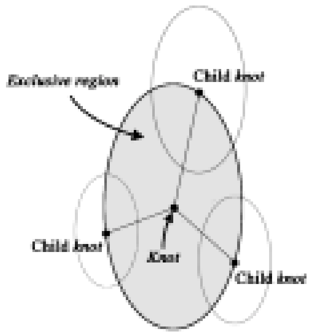
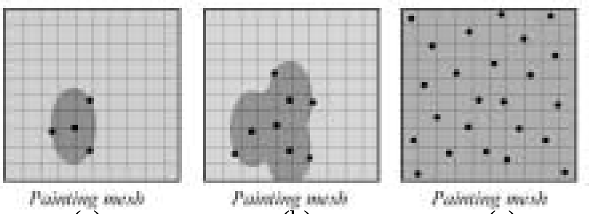


Figure 11. A knot litters its children on the boundary of exclusive region.



(a) (b) (c)

Figure 12. Process of placing knots in the painting mesh.

(a) A knot is randomly placed in the painting mesh.
(b) Knots litter children on the boundary of exclusive region recursively.
(c) Process stops while the whole the painting mesh is occupied with exclusive regions.

If we want to paint regular rock textures, we need to distribute strokes uniformly. Otherwise, if rock textures are chaotic, non-uniform distribution is applicable. Since strokes are generated by *knots*, we can control stroke distribution via changing the *knot* distribution. For example, if we uniformly distribute the children of a *knot* on the *exclusive region* boundary, all *knots* will be uniformly distributed in the *painting mesh*. In this case, texture strokes are regularly distributed. We could freely specify the *knot* distribution policy to achieve expected stroke distribution.

4.2 Fiber Length

While painting hemp-fiber texture strokes, long strokes present a continuous physiognomy of rock, and short strokes make the rocks look rough and scrappy. Since strokes are constrained in the 10×10-grid *painting mesh*, we limit the stroke length from 1 to 10. Under this mechanism, the length of a stroke means how many squares this stroke overstretch in Y direction of a *painting mesh*. As shown in Figure 13, if we start a stroke from square(5,1) and length of this stroke is 5, this stroke may terminate at square(5,6). Because we specify "which" square but not "where" to start or terminate a stroke, the actual lengths of strokes are similar but not the same. Figure 14 shows strokes with different length.

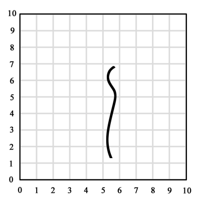
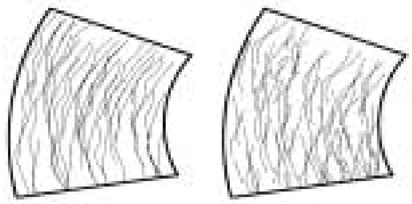


Figure 13. Length of strokes are ranged from 1 to 10.



(a) (b)

Figure 14. Strokes with average length (a) 8 and (b) 5.

4.3 Crossing Angle

Since a *knot* could generate two strokes, which cross each other at the *knot*, we may control orientation of strokes by crossing angles between these two strokes. In Chinese Landscape Painting, the orientation and intertwinement of rock strokes are very important. Especially in Hemp-fiber Stroke, strokes should follow some particular direction and intertwine with each other. Consider Figure 15, we suppose that a *knot* generates two strokes, the *primary stroke* and the *secondary stroke*. **Tp** and **Ts** denote tangent of the *primary stroke* and *secondary stroke* at the *knot* respectively. We classify crossing angles into two categories: α and β. α is between **Tp** and **X-axis**, and β is between **Tp** and **Ts**. While generating crossed strokes at a *knot*, orientation of the *primary stroke* is determined according to the α. Similarly, orientation of *secondary stroke* is determined according to the β.

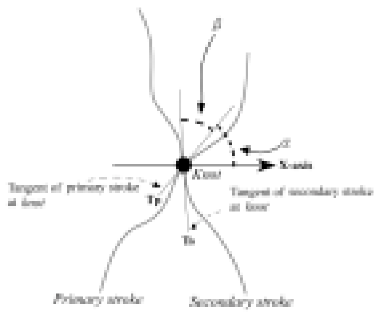
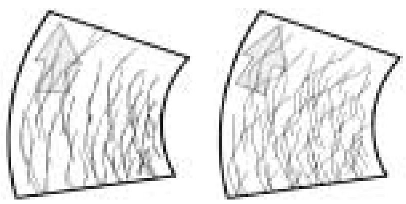
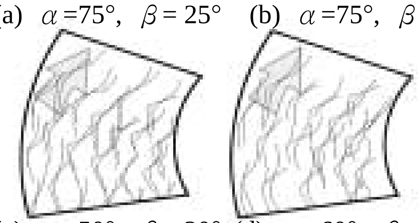


Figure 15. Orientation of strokes generated by a common knot depends on the α and β.

Figure 16 shows different values of α and β resulting in different orientation of strokes. Besides, we control the stroke intertwinement by β.



(a) α=75°, β= 25° (b) α=75°, β= 40°



(c) α=50°, β= 30° (d) α=60°, β= 40°

Figure 16. Strokes with different α and β form different stroke orientations global.

4.4 Perturbation

Visually, hardly perturbed strokes make rock surfaces look more undulating. For presenting various rock surfaces, we should take stroke perturbation as an important parameter. Since the strokes are represented in Cardinal Spline, we may perturb the curve by moving control points. Consider Figure 17, for each stroke, we locate a control point in each row where this stroke overstretch in a *painting mesh*. These control points could be moved in a proper range. If we apply perturbed strokes, moving range of each control point is amplified at the same time. Large moving range implies that control points can not be controlled at a fix location, and it results in perturbed strokes. Figure 18 shows difference stroke perturbation.

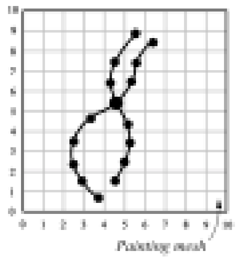
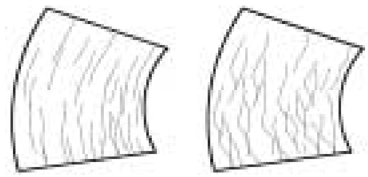


Figure 17. Perturb strokes by moving control points randomly in each painting mesh.



(a) No perturbation, (b) perturbation level 3

Figure 18. Strokes with different perturbation levels

5. Brush Strokes Technique

While painting, our brush model will move along the path of stroke and deposit ink on the canvas. In section 5.1, we introduce our brush model. It is a hierarchical object consisting of bristles. The deposited ink is blended with the color on the canvas. The ink blending mechanism, which is described in section 5.2, simulates this process.

5.1 Brush model

In Chinese Landscape Painting, rock textures are usually depicted with dry brush. The painter's brush dip a little ink, so ink deposited by bristles may be discontinuous during the whole painting process. Because dry brush makes strokes look more rough, it depicts rock sculpture well. Figure 19 is a dry brush example.

Figure 19. The dry brush effect of our system.

While painting rock textures, variation of the stroke width accompanies the change of brush orientation.User specify brush radius at each control point. But it is not convenient because rock textures consist of large number of strokes. If we specify brush radius point by point, it takes too much time. Horace [4] used an ellipse to simulate the contact region of the canvas and brush. This mechanism makes his brush model performs well in turning effect. We introduce a parameter, called *axes ratio* ρ, which means the ratio of the short axis and the long axis of the contact region. By rotating the ellipse slightly, we simulate variation of stroke width caused by stroke turning. Figure 20 shows different axes ratio to generate different stroke width. Figure 21 presents strokes generated by circle and ellipse respectively.

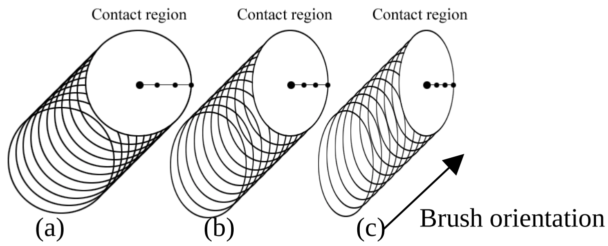


Figure 20. Contact region with axes ratio

(a)1 (b)0.67 (c)0.5

(a) a circle (b) an ellipse.

Figure 21. The strokes generated.

While painting rock contours, painters usually slow down the speed of brush movement and increase brush pressure to depict verve of the rock. So stroke pressure should be involved. In our system, the pressure P is ranged from 0 to 1. P determines whether bristles touch the canvas and quantity of ink deposited on the canvas. Consider Figure 22. For each bristle b_i, the pressure weight W_p is defined as:

$$W_p = \begin{cases} 0 & , \quad if \quad \dfrac{|b'_{i,y} - B|}{2 \cdot B} \geq P \\ \left(\dfrac{|b'_{i,y} - B|}{2 \cdot B \cdot P}\right) \cdot (P-1) + 1, & if \quad \dfrac{|b'_{i,y} - B|}{2 \cdot B} < P \end{cases} \qquad (1)$$

where

$b'_{i,y}$ is y-coordinate of b_i in the contact region.

B is the long axis of the contact region

Ink D_p deposited from a bristle is obtained by:

$$D_p = D \cdot W_p \qquad (2)$$

where D is the ink stored in the bristle.

According to Equations (1) and (2), even the same bristle has different D_p when the P is varied. Each bristle has its own W_p, and W_p is varied with P. Bristles with zero W_p do not touch the canvas; oppositely, bristles deposit ink on the canvas when W_p is nonzero.

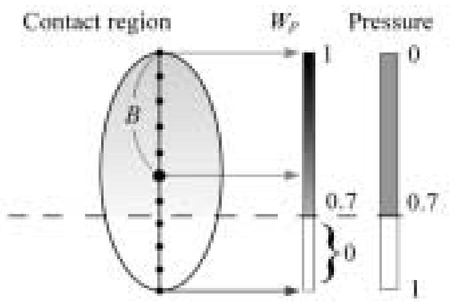


Figure 22. Pressure affects ink deposited on the canvas.

(a) The regular pressure 0.4, pressure on turning points 0.6.

(b) The regular pressure 0.6, pressure on turning points 0.8.

Figure23. While strokes turning, the pressure is increasing.

6. Results

In this section, the implementation and results are presented. The algorithms are implemented in C language on PC with a PII 400 CPU and 128 MB RAM.

Figure 24 is the texture stroke areas and the corresponding *painting meshes* of a rock, which is applied different stroke styles in Figure 25. Table 1 is the brush parameters of Figure 24 (a) and (b). Our system may imitate the real scene into Chinese Landscape Painting. Figures 26(a) is photos of Hua Mountain (華山), which is a famous mountains of China. We generated corresponding ink paintings of it in Figures 26(b). Mountains of real paintings usually consist of various styles of texture strokes. Figure 27 is a picture painted by Huang Gung-Wang (黄公望). We counterdrew Figure 27 with various styles of Hemp-Fiber Stroke (披麻皴), and the result is shown in Figure 28. Our brush model also performs well in Chinese Ink Sketch. Figure 29 is an ink sketch depicted by a Chinese painter of Ch'ing dynasty, Huang Pin-Hung (黄賓虹). We copy it with our system, and the result is shown in Figure 30.

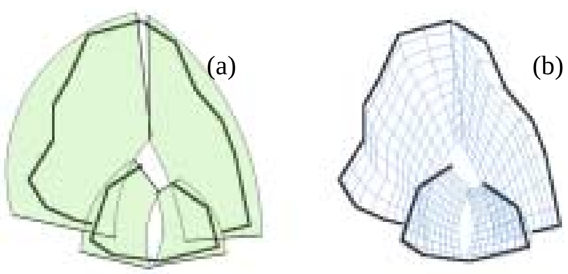
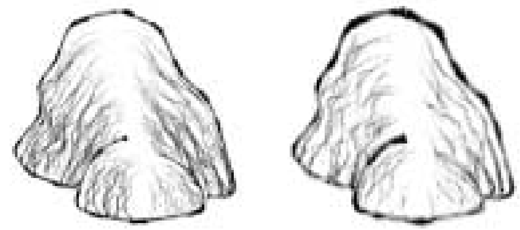


Figure 24. (a) Texture strokes areas and (b) corresponding *painting meshes* of a rock.

Table.1 Stroke parameters of Figure

Figure	Contour stroke size	Texture stroke size	Minimum brush pressure
25 (a)	5.0	4.0	0.4
25 (b)	10.0	6.0	0.2



(a) (b)

Figure 25. Resulting images of Figure 24.

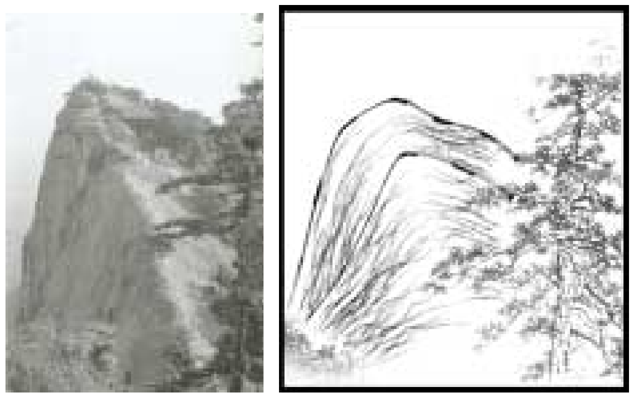


Figure 26. (a)A scene of Hua Mountain (華山).
(b)The Chinese painting of Hua Mountain.
(ps:Trees are synthesized by the post process.)

Figure 27. An Chinese painting by Huang Gung-Wang.

Figure 28. The image counterdrawn from Figure 27. (Trees in the picture are synthesized by post process.)

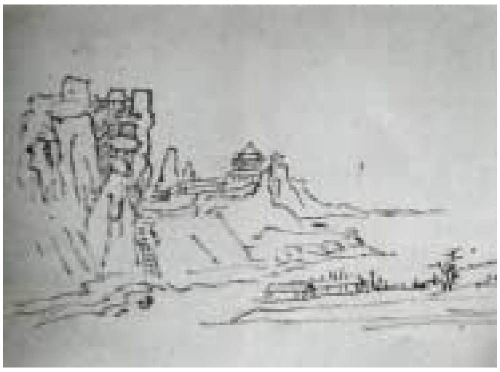


Figure 29. An ink sketch depicted by Huang Pin-Hung

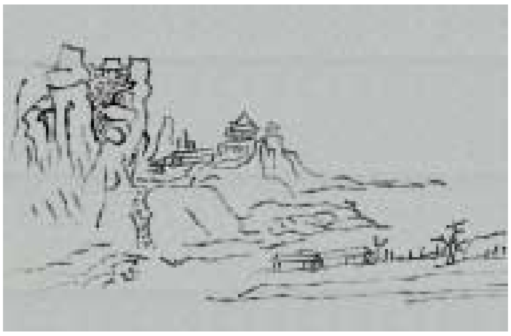


Figure 30. The image imitating Figure 29 with our brush model

7. Conclusions And Future Works

In this paper, we propose a method to synthesize rock textures in Chinese Landscape Painting. Users just specify the rock contour, texture stroke areas, and stroke parameters, then our system will underwrite the whole painting process. People do not need to be familiar with painting skills, and they could paint out various styles of rocks in Chinese Landscape Painting. The advantages of our system are:

(1). It saves the time of trying error.

(2). It generates various styles of rocks in short time.

In the future, there are still some issues to enhance our system.(1). Our system focused on Hemp-Fiber Stroke. Although it is the major stroke in Chinese Landscape Painting, there are still lots of other strokes should be integrated in our system. Since the concept of texture strokes area is highly capable, it will not be too hard to integrate other strokes.

(2). We conducted three kinds of basic contour structures in a texture strokes area. Since Chinese Landscape Painting is varied abundantly, it is not enough to paint highly complex rocks. In Chinese Landscape Painting, grand mountains or rocks usually consist of complex contours. So, improving our system to recognize more contour structures will help user to paint more complex rocks.

(3). Our brush model does not emphasize turning effects of brushwork. But skills in Chinese Ink Painting are derived from Chinese Calligraphy in many aspects. We can improve our brush model to synthesize more realistic stroke effects in Chinese Landscape Painting.

Besides, our system also can be integrated with other rendering and animation systems to generate more impressive rendering results.

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