The Synthesis of Rock Textures in Chinese Landscape Painting

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Abstract

In Chinese landscape painting, rock textures portray the orientation of mountains and contribute to the atmosphere. Many landscape-painting skills are required according to the type of rock. Landscape painting is the major theme of Chinese painting. Over the centuries, masters of Chinese landscape painting developed various texture strokes. Hemp-fiber and axe-cut are two major types of texture strokes. A slightly sinuous and seemingly broken line, the hemp-fiber stroke is used for describing the gentle slopes of rock formations whereas the axe-cut stroke best depicts hard, rocky surfaces. This paper presents a novel method of synthesizing rock textures in Chinese landscape painting, useful not only to artists who want to paint interactively, but also in automated rendering of natural scenes. The method proposed underwrites the complete painting process after users have specified only the contour and parameters.

1. Introduction

Computer graphics-related research has focused on obtaining photorealistic images. However, photorealism is occasionally not the most effective means of visually expressing emotions. Accordingly, photographs can never entirely replace paintings. Non-photorealistic rendering (NPR) approaches have recently received renewed interest. Researchers have begun to study how a photograph or a photorealistic image may be made to look like a painting.

Until now, most research [3,7,10,11] into NPR has focused on Western painting. Lots of painting algorithms have been written to convert a photorealistic image into an art form such as an oil painting or watercolor. Typically, such a painting style is created by applying masks [3,10] or by placing user-defined pattern [7,11]. These methods deliver good results for Western painting. But these approaches are not appropriate to Chinese ink painting. Generally, Western painting involves more precision but Chinese ink painting is more abstract.   However, strokes in Chinese ink painting are in many aspects based on Chinese brushwork, including color filling, pattern placing and describing details with various brush sizes and techniques.

This paper presents a novel method for synthesizing Chinese landscape painting. Individuals simply sketch the contours of rocks and texture stroke areas according to rock textures in a Chinese landscape painting. Our method then takes over runs the entire painting process, saving the time involved in trial and error, and attempting to synthesize painting styles.

1.1 Previous Works

Depending on the style of painting, NPR research [3,7,9,10,11,15] focuses on different aspects. For example, although a proper brush model is vital when simulating a Chinese ink painting, color distribution is the most important aspect of oil painting. NPR research is categorized into three steps. First, photorealistic images are transformed into non-photorealistic images [3,7,10,11]. Mapping various user-defined textures or patterns onto an image subsequently generates different styles of the non-photorealistic image. Second, images such as illumination or lighting direction are analyzed to generate various sketches [9,15]. Images generated during this step are normally a monochrome, and a stereo is present via distribution and density of sketching strokes. The third step focuses on the brush and painting model [1,4,12,16,17] in which strokes and ink effects are common, particularly in Oriental paintings. This step is adopted herein since this work generates texture strokes and paints them with a proper brush model.

2. Chinese Landscape Painting

In the Tang dynasty[+], the range of subjects in painting expanded and landscape became established as a distinct category. Chinese landscape painting provided a more spontaneous style that captured images in abbreviated suggestive forms. Chinese landscape painting has been cultivated by masters through a long evolution, into an exquisite art form.

Rocks are primary objects in Chinese landscape painting because of their power to create the mood. Artists use the Chinese character TSUN, also meaning wrinkles, to represent texture strokes when applied to rock formations. Over the centuries, masters of Chinese landscape painting developed various TSUN techniques. *Hemp-fiber* strokes (Fig. 1) and *axe-cut* strokes (Fig. 2) are two major types of TSUN techniques. A slightly sinuous and seemingly broken line, the *hemp-fiber* strokes is used for describing the gentle slopes of rock formations, whereas the *axe-cut* strokes most accurately captures hard, rocky surfaces.

Figure 1: *Hemp-fiber* texture strokes by Huang Gung-Wang.

Long *hemp-fiber* strokes express relatively smooth surfaces, while short *hemp-fiber* strokes indicate a more wrinkled surface. Developed by the great Southern School master Tung Yuan (907- 960 AD), the short *hemp-fiber* strokes were varied and generally favored by the literati painters, who dominated mainstream Chinese landscape painting, beginning with the emergence of the Four Masters of the Yuan dynasty[+]. The most important of the four Masters, Huang Gung-Wang (1269-1354 AD), practiced the strokes in a loose, calligraphic fashion.

The *axe-cut* texture strokes developed earlier during the Sung dynasty[+] by Li Tang (1049-1130 AD). These simplified yet natural slanted brushstrokes depict earthen forms and hills. The stroke also effectively describes angularly shaped rocks of crystalline quality and sedimentary rocks displaying layered structures.

[+] Tang dynasty (618-907 AD), Sung dynasty (960-1279 AD), Yuan dynasty (1279-1368 AD)

The best-known exponents of the *axe-cut* strokes are Ma Yuan and Hsia Kwei, associated with the Northern School of landscape painting, which particularly thrived in the Sung dynasty[+].

Figure 2: *Axe-cut* texture strokes by Hsia Kwei.

Chinese landscape painting with texture strokes is characterized by the following procedure:

(1) An artist begins to visualize a land formation with external contours, which define the overall shape. Internal contour, as added to imply folds on the slopes, reveals the position and direction of the ridge and determines its volume.
(2) After the internal contours are defined, texture strokes are applied in the area.
(3) Texture stroke is used to symbolize the rock formation.
(4) Finally, the brush moves along the path of the stroke and deposits ink on the rice paper.

3. Brush Model

The application of the brush is an essential element of landscape painting techniques. Brushwork is very important in Chinese ink painting. A brush consists of a bundle of bristles. Where the brush contacts the rice paper, the footprints of the bristles form a contact region. While painting, these bristles deposit ink on the circular region in contact with the rice paper, as shown in Fig. 3.

The contact region is a 2D ellipse. Consider in Fig. 3, an ellipse C, with center o, as the contact region between the brush and rice paper. A and B are the short axis and long axis of C, respectively. A set of bristles is distributed inside the circle. We denote each bristle as b_i, and represent it in polar coordinates with respect to the center of the ellipse C.

$$b_i = (d_i, \theta_i) \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots(1)$$

where i is the bristle index. d_i is the distance from o to b_i. θ_i is the angle between x-axis and $\overline{ob_i}$. Herein, the central angle of C is split equally to obtain the base

angle, θ_{base}, such that θ_i is $i \cdot \theta_{base}$. For each θ_i, we locate the number of bristles on the radius. Two parameters allow the number of bristles to be controlled: one is the base angel θ_{base}, and the other is the number of points located on the radius. A smaller base angle and more located points both result in more bristles. Parameters may be adjusted to obtain different brush sizes and resolutions.
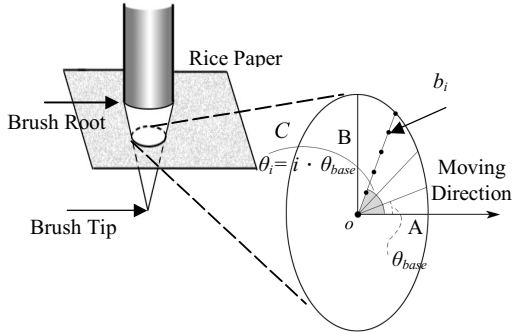

Figure 3: Brush Model.

3.1 Motion Mechanism

During painting, the contact region moves along the stroke trajectory and deposits ink to generate strokes. The stroke trajectory is constructed by Cardinal spline. The curve may be interpolated between two neighboring control points. The center of the contact region travels along these interpolated points, leading circumferential bristles and leaving footprints on the rice paper. Assume the center of the contact region on the rice paper is (O_x, O_y). The position of bristle b_i is given by Equation (1):

$$b_{i,x} = o_x + b'_{i,x} = o_x + [d_i \cdot \cos\theta_i - d_i \cdot \sin\theta_i] \quad ....(2)$$
$$b_{i,y} = o_y + b'_{i,y} = o_y + [d_i \cdot \sin\theta_i + d_i \cdot \cos\theta_i]$$

where $b_i = (b_{i,x}, b_{i,y})$. The width of the strokes is controlled by the axial lengths of the contact region, specified at each control point. The axial lengths of interpolated points are linearly interpolated between two neighboring control points.

During painting, brush orientation continuously changes, and brush orientation is an important parameter. Consider Fig. 4. When the brush moves from point (x_i, y_i) to point (x_{i+1}, y_{i+1}), the moving orientation is determined by the tangent of (x_i, y_i) on the track. In a discrete environment, orientation can be approximated

by: $\quad T(x_i, y_i) = \dfrac{y_{i+1} - y_i}{x_{i+1} - x_i}$ ....(3)

$$\theta = \tan(T(x_i, y_i))^{-1}$$

where $T(x_i, y_i)$ is the tangent of (x_i, y_i). Bristles in a

contact region are rotated by θ with respect to the center of the contact region. The equation giving the new coordinates of the bristles is derived from Equation (2):

$$b_{i,x} = o_x + [b'_{i,x} \cdot \cos\theta - b'_{i,y} \cdot \sin\theta] \quad ....(4)$$
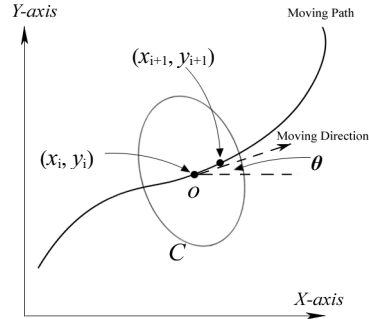$$b_{i,y} = o_y + [b'_{i,y} \cdot \sin\theta + b'_{i,y} \cdot \cos\theta]$$

Figure 4: Brush rotates to follow the moving direction.

3.2 Ink Effects

To present rock textures in Chinese landscape painting, more parameters are required to describe ink effects.

Ink Decreasing (λ_1) : Ink quantity decreases as the brush moves along the rice paper. Thus, less ink is deposited on the rice paper.

Ink Soaking Variation (λ_2) : The concentration of ink in the brush varies, due to the ink itself or the action of the painter. Ink concentration is linearly interpolated in the contact region.

Bristle Material (ρ) : Generally, bristles are made of animal's fur (e.g. Sheep or wolf). A random number added to each bristles. The variance of distribution of the random number is lower to express softer bristles, whereas the variance is larger to express harder bristles.

Bristle Dry-Out (Δd) : Painting with a dry brush may cause bristles to run out of ink and leave gaps along the trajectory of the brush, due to fast evaporation.

Wet Effect (μ) : Water quantity determines the gradient of the ink. The dry brush makes strokes rougher, whereas the wet brush creates more smooth strokes.

Ink Blending : Since absorption has an important effect on painting. Ink blending is conveniently expressed in gray scale, from 0 to 255 black to white. The blending equation is

$$inkNew = inkP \cdot \dfrac{inkB}{255} \quad ....(5)$$

where *inkNew* is the ink value after blending, *inkP* is the ink value before blending, and *inkB* is the ink value of the brush.

4. Rock Contour

When rocks are painted, their contours are normally drawn before texture strokes are applied. Most previous automatic painting systems use a series of small brush strokes, identical except from their color and orientation, or simultaneously apply pigment to large regions of an image. In order to draw rock contour and *hemp-fiber* strokes, a method for painting long, continuous curves is offered here.
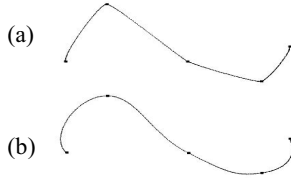

Figure 5: Cardinal Curves with different *t*.
(a) hard rock's contour (*t* = 0.2).
(b) soft rock's contour (*t* = -0.5).

The rock contour is constructed using the precise and flexible Cardinal spline. Cardinal spline is an interpolated but not approximated curve, which passes through all the specified control points. Feature points of the rock contours can be selected as control points. The other advantage of Cardinal spline is its flexibility. Rocks can be painted softer or harder. Cardinal spline enables slackness control by changing parameter *t*. A smaller *t* implies a slacker curve. Figure 5 displays the precision and flexibility of the Cardinal spline.

While painting rock contours, painters normally slow the brush movement and increase the brush pressure to capture the verve of the rock. The pressure P is varies from 0 to 1. P determines whether bristles touch the rice paper and the amount of ink deposited. For each bristle b_i, the pressure weight Wp is defined by,

$$W_p = \begin{cases} 0 & , \ if \ \ \dfrac{|b'_{i,y} - B|}{2 \cdot B} \geq P \ \ \cdots\cdots(6) \\[2ex] \left(\dfrac{|b'_{i,y} - B|}{2 \cdot B \cdot P} \right) \cdot (P-1)+1, & if \ \ \dfrac{|b'_{i,y} - B|}{2 \cdot B} < P \end{cases}$$

Where $b'_{i,y}$ is the y-coordinate of b_i in the contact region, and B is the long axis of the contact region. According to Equation (6), even the same bristle exhibits a different deposited ink as P changes. Figure 6 shows different values of pressure, yield different stroke styles applied with Cardinal spline.

Figure 6: (a) Pressure on turning points = 0.6.
(b) Pressure on turning points = 0.8.

5. Hemp-Fiber Texture Strokes

In Chinese landscape painting, painters cluster various strokes to depict stuff of rock surfaces. The different rock textures are generated by changing stroke distribution, ink density, stroke length, and something else. In our approach, the knot and exclusive region are used to control the distribution and density of strokes. In this section, we introduce several parameters: length, crossing angles, and perturbation. Stroke styles are presented with the three parameters. With different combinations of spatial and style parameters, users can generate various *hemp-fiber* strokes.

5.1 Texture Strokes Area

The area surrounding the texture strokes is a region where only one style of rock textures is applied. In addition, an area surrounding the texture strokes is equipped with a painting mesh, which consists of 10×10 grids, to control the orientation and distribution of texture strokes. There are three steps for making a painting mesh as follows: (1) corner vertices adaption, (2) boundary vertices interpolation, and (3) interior vertices generation.
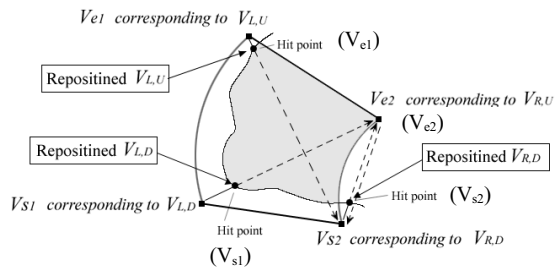

Figure 7: The process of corner vertices adaption.

According to four user-specified points, the corner vertices of painting mesh can be obtained in the region of the rock. Figure 7 shows the four point V_{LU}, V_{LD}, V_{RU}, and V_{RD}, which are specified by user. Where V_{e1} is the repositioned point of V_{LU} with the intersection of line $\overline{V_{LU}V_{RD}}$ and Cardinal path of rock contour. By the same way, the other three corner vertices can be found. In step 2, there are nine boundary vertices obtained by interpolating the positions of each pair of neighboring corner vertices. Finally, using vector operation to obtain the interior vertices. Since the painting mesh is subdivided into 10×10 grid uniformly, the blending function is linear. Figure 8 shows the process. After step 3, a painting mesh wraps up the actual-painting region tightly.

According to Fig. 8(d), although an area surrounding the texture strokes encloses a region, the texture is applied inside the rock contour that is grayish color.

Coordinates of each grid point of a painting mesh are mapped to the region where textures are applied.
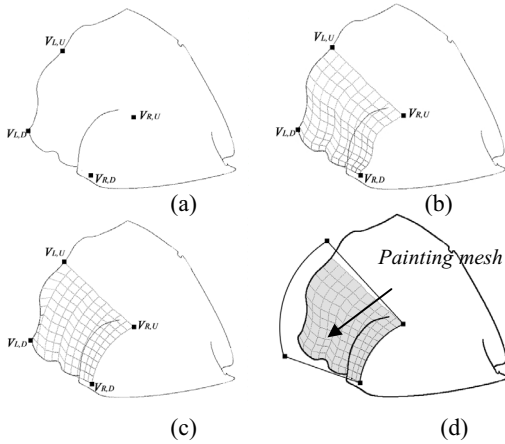

Figure 8: The texture strokes area and painting mesh.
(a) The positions of corner points after step 1.
(b) Interior vertices generation according to left side.
(c) Interior vertices generation according to right side.
(d) The painting mesh after blending (b) and (c).

5.2 Distribution and Density

In our approach, the distribution and density of strokes are taken as spatial parameters. They present illumination effects, which make the painted rock stereo. Dense strokes are applied to dark rock surfaces and sparse strokes are applied to bright rock surfaces. Moreover, knot and exclusive region are used to control both of them. Consider Figure 9. A knot can generate one or two strokes. If a knot generates two strokes, 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 is then placed in the painting mesh, subsequently generating strokes to mold rock textures. Therefore, distribution of knots determines the distribution of strokes. Notably, an exclusive region is involved to control the knot distribution and density.
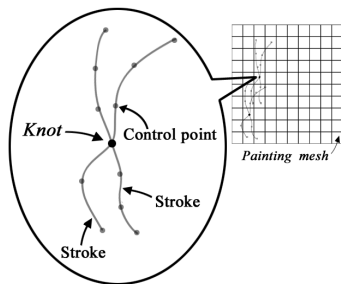

Figure 9: Two strokes generated by a knot.

5.3 Fiber Length

When *hemp-fiber* texture strokes are painted, long strokes present a continuous physiognomy of rock, and short strokes make the rocks appear rough and coarse. 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 refers to how many squares this stroke overstretches in Y direction of a painting mesh. 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 10 shows strokes with different average lengths.
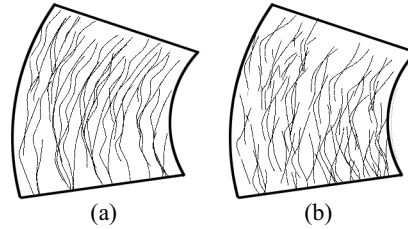

Figure 10: (a)Average length =8; (b)Average length =5.

5.4 Crossing Angle

A knot can generate two strokes, which cross each other at the knot, accounting for why the orientation of strokes can be controlled by crossing angles between these two strokes. In Chinese landscape painting, the orientation and intertwinement of rock strokes are essential. Particularly in hemp-fiber strokes, strokes should follow some particular direction and intertwine with each other.
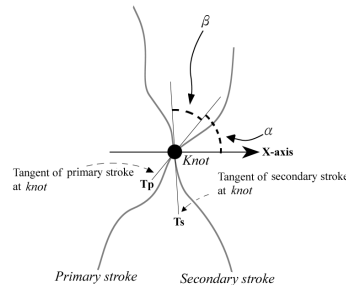

Figure 11: Orientation of strokes generated by a common knot depends on the α and β.

Consider Figure 11. Assume that a knot generates two strokes, the primary stroke and the secondary stroke. Where Tp and Ts denote the tangent of the primary stroke and secondary stroke at the knot, respectively. Herein, crossing angles are classified into two categories: α and β. Where α is between Tp and X-axis, and β is between Tp and Ts. When crossed

strokes are generated at a knot, orientation of the primary stroke is determined according to α. Similarly, orientation of secondary stroke is determined according to β. Figure 12 shows different values of α and β, resulting in different orientations of strokes. Besides, β is used to control the stroke intertwinement.
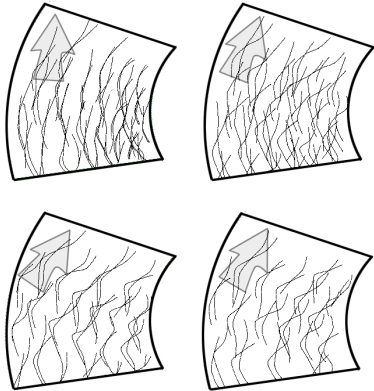

Figure 12: Strokes with different α and β.

5.5 Perturbation

Visually, slightly perturbed strokes make rock surfaces appear more undulating. For presenting various rock surfaces, stroke perturbation should be considered an important parameter. Owing to that the strokes are represented in Cardinal spline, the curve can be perturbed by moving the control points. For each stroke, a control point in each row is located, where this stroke overstretches in a painting mesh. These control points can be moved in a proper range. If perturbed strokes are applied, the moving range of each control point is amplified simultaneously. A large moving range implies that control points can not be controlled at a fixed location.

6. Axe-Cut Texture Strokes

The *axe-cut* stroke has played a very important role in the development of Chinese landscape painting. It is the superior texture stroke to depict very hard rock. The *axe-cut* stroke is a large slanted stroke similar to that an axe used to cut wood. An artist slants the brush such that the brush tip is bent slightly to one side. Normally, the stroke has a rectangular or a triangular shape. (Fig. 13)

6.1 Texture Strokes Area

The texture stroke area is the same as the *hemp-fiber* stroke area. The area surrounding the texture strokes is a region where only a single rock texture is applied.

Furthermore, the distribution of the *axe-cut* strokes is very regular. The strokes are applied one by one inside the rock contours with a small overlap.
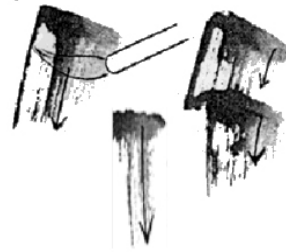

Figure 13: *axe-cut* texture strokes.

6.2 Pressure Function

The pressure function is the most important factor of the *axe-cut* stroke and determines the number of bristles that touch the rice paper and the quantity of ink deposited. We construct the basic pressure function as shown in Fig. 14.

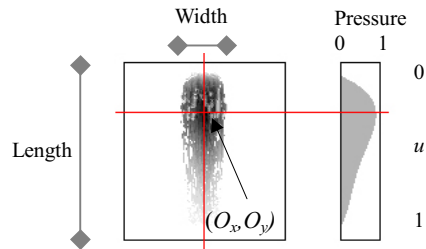$$P(u) = u(1-u)(a_1(1-u)^2 + b_1(1-u) + c_1)\ldots\ldots(7)$$

Figure 14: Single *axe-cut* texture stroke.

Where u is transferred from the length of the *axe-cut* stroke to (0,1), a_1, b_1 and c_1 are constant. The value of P(u) lies between 0 and 1. The pressure is 0 at both the start point and the end point. The center of the *axe-cut* stroke is at (O_x, O_y).
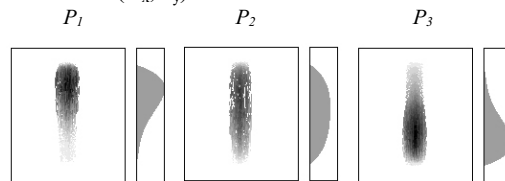

Figure 15: Pressure functions of *axe-cut* stroke.

$$P_1 = u(1-u)(a_1(1-u)^2 + b_1(1-u) + c_1)$$
$$P_2 = u(1-u)$$
$$P_3 = u(1-u)(a_3 u^2 + b_3 u + c_3)$$
$$Pressure = K_1 P_1 + K_2 P_2 + K_3 P_3 \quad \ldots\ldots \quad (8)$$

Generally, changes of pressure are very complex in painting. The other two pressure functions P_2 and P_3

can also be constructed. Finally, the pressure function is combined with P_1, P_2 and P_3. (Fig.15)

6.3 Discontinuity

A brush dries out when the amount of deposited ink is under a threshold. Two directional discontinuity factors, one is horizontal and the other is vertical to simulate this effect. The maximum gap size is predefined for vertical directional discontinuity. Once a bristle deposits ink discontinuously, the corresponding gap size can not exceed the maximum gap size. The gap size decreases until it equals zero during the brush moving. A random number is defined for each bristle in the horizontal directional discontinuity, and is added to the ink concentration in the bristle, making the ink color darker or lighter. The discontinuity is also dependent on bristles' material and wet effect.

6.4 Experiment Examples

Many styles of *axe-cut* strokes can be generated according to the above parameterization. Figure 16 displays about ten *axe-cut* strokes and blending effect. Strokes with the same pressure indicated on the left are shown in the same row. Table 1 lists the corresponding parameter's value.
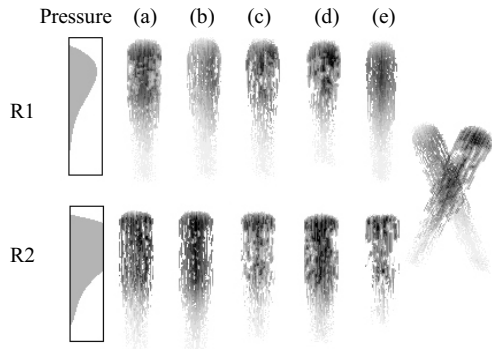

Figure 16: Ten *axe-cut* strokes and blending sample.

		(a)	(b)	(c)	(d)	(e)
R1	λ_1	0.6	0.23	0.6	0.8	0.6
	λ_2	0.3	0.4	0.6	0.8	0.4
	ρ	7	6	12	10	6
	Δd	46	36	61	65	25
	μ	80	130	130	100	150
R2	λ_1	0.6	0.5	0.5	0.5	0.36
	λ_2	0.3	0.5	0.3	0.5	0.34
	ρ	12	6	14	18	30
	Δd	47	47	76	36	100
	μ	170	170	100	100	124

Table 1: The corresponding parameters of Fig. 16.

7. Results

Figure 17 illustrates the area surrounding the texture strokes and the corresponding painting meshes of an original painting by Huang Gung-Wang shown in Fig. 1. Figure 18 is the resulting image from Fig. 1; Table 2 gives the brush parameters of Fig. 18. Figure 19 shows the resulting image from Fig. 2 with *axe-cut* texture strokes by our method.
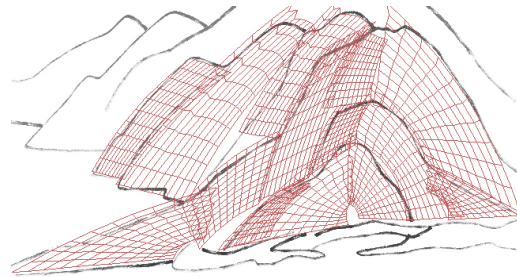

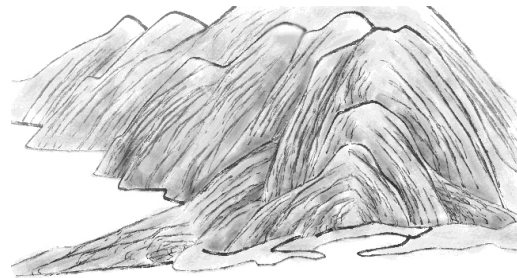**Figure 17:** Stroke areas and painting meshes of Fig. 1.

Figure 18: Resulting image of Fig. 1 by our method.

Number of painting mesh	Stroke's size	Turning point pressure	Cardinal spline (t)
18	2	0.4	0.2

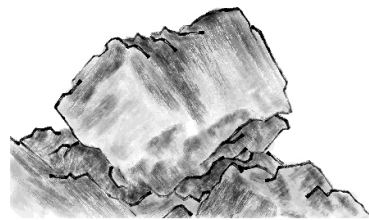**Table.2:** Stroke parameters of Fig. 18

Figure 19: Resulting images of Fig. 2 by our method.

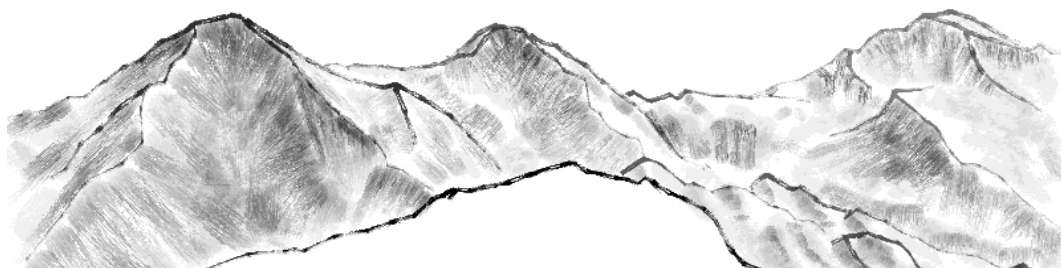**Figure 20:** Jungfraujoch-Top of Europe.

Figure 21: Jungfraujoch-Top of Europe with axe-cut texture strokes.

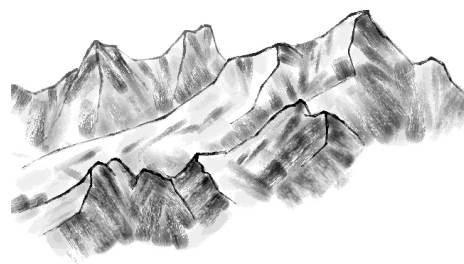**Figure 22:** "Titlis Mountain", by Lin Yu-Shan.

Figure 23: Imitate "Titlis Mountain".

Our methods may also depict a real scene into Chinese landscape painting. Figure 20 displays photographs of Jungfraujoch Mountain – "Top of Europe". Figure 21 illustrates corresponding ink paintings generated with *axe-cut* texture strokes by our method. Figure 22 shows the picture "Titlis Mountain", by Lin Yu-Shan who is a famous artist in Taiwan. Figure 23 summarizes those results of "Titlis Mountain" by our method. Finally, Fig. 24 is a photograph of Lan-Yan River in Taiwan. Figure 25 shows the Lan-Yan River with *hemp-fiber* texture strokes.

Figure 24: Lan-Yan River in Taiwan

Figure 25: Lan-Yan River with *hemp-fiber* strokes.

8. Conclusion and Future Works

Over the centuries, masters of Chinese landscape painting have developed various texture strokes. A slightly sinuous and seemingly broken line, the *hemp-fiber* stroke, is used to describe the gentle slopes of rock formations, whereas the *axe-cut* stroke most accurately depicts hard, rocky surfaces.

This paper presents a novel method of synthesizing rock textures in Chinese landscape painting, useful not only to painters, but also for automated rendering of natural scenes. The method herein underwrites the complete painting process after a user has specified only contours and parameters. For example, a user can synthesize a Chinese painting based on a reference image or figure. By allowing users to reuse all conventional strokes, the tedium of real ink painting can be reduced and time saved. Individuals can achieve various styles of Chinese landscape painting without familiarity with painting.

Future studies should address the following issues to advance our ideas.

(1) Our paper focuses on using the *hemp-fiber* and *axe-cut* strokes. Although these are the major texture strokes in Chinese landscape painting, many others should be developed. Developing other strokes would not be too difficult since the concept of texture strokes is very similar to *hemp-fiber* and *axe-cut* strokes.

(2) Our brush model does not emphasize the water effects of brushwork. However, water blending in Chinese ink painting is very important. Our brush model could be improved to synthesize more realistic stroke effects.

(3) Automatically generating Chinese landscape paintings from any landscape photo picture is a great challenge. Our method could be applied to this problem if integrated with image processing technology.

Acknowledgement

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