Image Based Synthesis of Chinese Landscape Painting

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Abstract This paper describes a new framework for synthesizing Chinese landscape painting using an image based approach. Our framework involves two stages: a preprocessing phase, in which a few brush stroke texture primitives (BSTP) are collected from samples of hand-made Chinese paintings, and the control picture is constructed to provide color ID of mountains, and the on-line phase, in which the fog image is synthesized and mountains are “drawn” by mapping multiple layers of BSTP guided by the control picture. In the case of more complex shading is needed, the shading picture is constructed and used during the BSTP mapping phase. Finally, the synthesized Chinese landscape paintings of a variety of styles are given and they look more close to the hand-made work than those produced with previous modeling methods.

Keywords Non-photorealistic rendering, image-based rendering, texture mapping, Chinese painting.

1 Introduction

This paper describes a framework for the synthesis of Chinese landscape painting using a few brush stroke texture primitives collected from samples of hand-made work. Chinese painting as a traditional art form in China differs from other art forms in its expressive brush strokes and ink effects. Attracted by its beauty, many researchers attempted to numerically model this medium using computer simulations. However the images produced so far are very simple objects such as fish, bamboo leaves, an orchid plant and rocks *etc* thus they are unable to demonstrate the characteristic of a typical Chinese painting fully, because the simulating models are far too simple to create complex expressive brush strokes.

Typically, Chinese painting is created by use of ink brush, ink stick, ink stone and *Xuan* paper. Chinese artists have long exploited the richness of ink brushes in a variety of styles, as a result, techniques of using brush and ink to produce more expressive brush strokes conveying the mood, feeling and emotions has become the core concern in Chinese painting. Technically, the brush can be used in different manners as shown in Fig. 1, the ink used in Chinese painting has been traditionally regarded as “colors” to represent tones and simple shading if blended with different amount of water, and diffusion of *Xuan* paper makes brush strokes exhibit numerous visual effects distinct from any other art medium in response to brush movements.

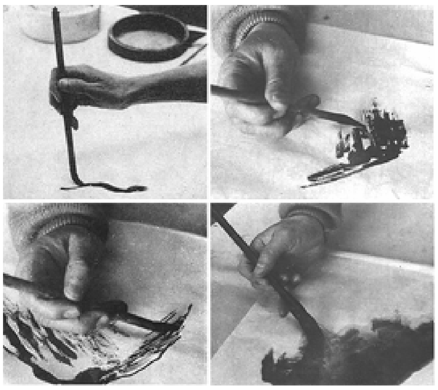

Fig. 1. Four main usages of the brush

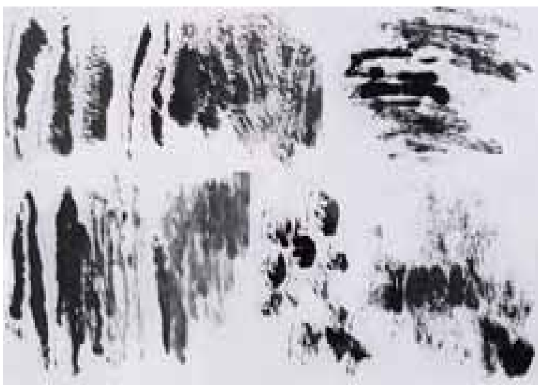

Fig. 2. Complex and expressive strokes

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In the context of Chinese landscape painting along, Chinese artists developed more than 30 *Cun* techniques to paint textures of mountains and stones and Fig. 2 gives a few examples of expressive brush strokes drawn on *Xuan* paper in Chinese landscape painting [1] .

Implementing all of these brush strokes and artistic effects automatically by numerical simulation remains an extremely difficult research endeavor. Our approach to these problems relies on the observation that, *in Chinese painting, although brush stroke texture may vary from painting to painting, or from artist to artist, to present different styles, the form described by the texture formed by those brush strokes remains unchanged.* We target the kinds of images made by artists and synthesize Chinese paintings with the effects we observe in those images. We started from paintings of landscape by some famous Chinese artists, in part because they connect the ancient with the modern in styles.

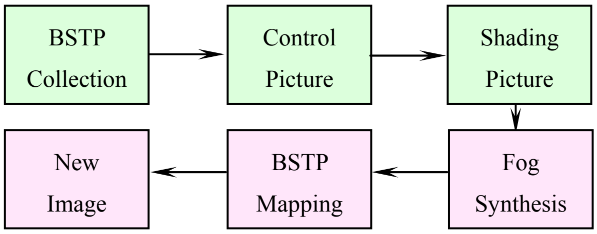


Fig. 3. Overview of our approach

We have developed a system to synthesize Chinese paintings that mimic the styles of selected samples. At a high level, our system proceeds in five steps as shown in Fig. 3.

First, during off-line preprocessing (upper three boxes), we collect BSTP from samples of hand-made work, this in part simulates the painting style of human artists. Second, during another preprocessing step, we construct the control picture by drawing mountains with different colors that serve as color ID of relevant mountains, and the shading picture that provides shading information of relevant mountains. Finally, during subsequent on-line sessions (lower three boxes), the fog image is synthesized and mountains are "painted" by mapping BSTP to yield a novel image. Our main contributions are the system architecture, the method of image synthesis using multiple seeds as constraints and the control mechanism of BSTP mapping using color ID provided by the control picture.

The remainder of the papers is organized as follows. In Section 2 we review background information and related work. Section 3 describes BSTP collections. Sections 4-8 address the main issues in construction of the control picture, shading picture, fog synthesis, BSTP mapping and mountain edge rendering. Section 9 presents results of synthesized paintings with different styles, while section 10 contains a brief conclusion and discussion of areas for future work.

2 Related Work

In general, non-pohtorealistic rendering (NPR) uses a variety of strokes to depict object shapes through image-based, model-based and hybrid approaches. Previous NPR work thus includes brush models as well as various techniques to place strokes on 2D images and 3D geometry of a scene.

2.1 Brush Models

In literature many brush models have been proposed[2-11], some of them attempt to simulate the effects of oriental ink brushes. Strassmann[10] modeled the ink-laying process of bristle brush on paper. The image left by a sopping wet brush dragged erratically across a sheet of textured paper can be generated by a representation that keeps track of the physical properties of the materials. Guo and Kunii[6] made an extension by including ink-diffusion through the paper fabric mesh. Pang *et al*[7] even attached real bristle brushes to plotters and defined the strokes by the paths and pen up/down control parameters. More recently, Lee[9] simulated the "soft" brushes by modeling their response elastically to the force exerted by an artist against the paper, and Way[10] *et al* focused on Chinese landscape paintings of Tang dynasty (618-907 AD) and Song dynasty (960-1279 AD) and synthesized rock textures by drawing *hemp-fiber* texture strokes and *Axe-cut* texture strokes respectively on the model constructed by the user. Jiao and Sun[11] simulated a number of typical ink wash effects by processing original brush stroke using fluid simulation, layer blending and color model. Those models mentioned above are however not able to produce the ink effects with the quality of expressive strokes shown in Fig. 2 because of their inherent simplicity in model structure.

2.2 Non-photorealistic Rendering

In recent years, there is a trend toward developing NPR techniques with a variety of styles and simulated media, such as impressionist painting[12-16], pen-and-ink[17-21], pencil rendering[22], watercolor[23], and the style of Dr. Seuss[24,25]. Much of this work has focused on creating still images either from photographs, from computer re-rendered images, or directly from 3D models, with varying degree of user-direction.

Several stroke-based NPR systems process an image for a painterly effect by placing a jittered grid of short brush strokes over an image[13-16,25,26]. Markosian *et al*[27] used the image moments of the color difference image to place rectangular brush stroke. Some other NPR systems take 3D scene description as input and make full use of 3D geometric and viewing information to produce non-photorealistic effects by placing strokes or drawing primitives either on surfaces or along the contours of surfaces[24,29,30]. The hybrid approaches[31,32] have built NPR/IBR systems where hand-drawn art is re-rendered for different views. Klein *et al*[33] presented a system to synthesize imagery of architectural interiors using stroke-based textures for interactive walkthroughs. Although some painterly rendering systems achieved better rendering results by using multiple passes to vary brush size and shape than those done using single pass techniques, they are still unable to change brush texture during the rendering phase to produce imagery more close to the hand-made work. Recently, Hertzmann *et al* used *Image Analogy* technique to process photo images into some artistic effects[34], the method however produces very poor results when dealing with Chinese paintings in the experiments done by Dr. Hertzmann, because Chinese paintings have different painting styles for different parts of the image, and their algorithm can't distinguish them. Nevertheless, their idea of image pairs in the training phase inspired authors to use the control picture in this work.

In this paper, we investigate a hybrid NPR/IBR approach. The architecture of our system enables us to vary brush stroke textures using multiple passes at different levels. The three main issues we address are: (1) collections of BSTP, (2) construction of the control picture and shading picture, (3) fog image synthesis, and (4) rendering of other still objects by mapping multiple layers of BSTP guided by the color ID provided by the control picture. These issues are the topics of the following five sections.

3 Brush Stroke Texture Primitive (BSTP) Collections

A typical Chinese landscape painting usually consists of mountains, fog, trees *etc*. The first issue in implementing our system is to collect suitable brush stroke textures from the sample paintings as BSTP. Note that the brush stroke textures here refer to textures formed by several brush strokes, and each stroke may still have its “internal” texture.

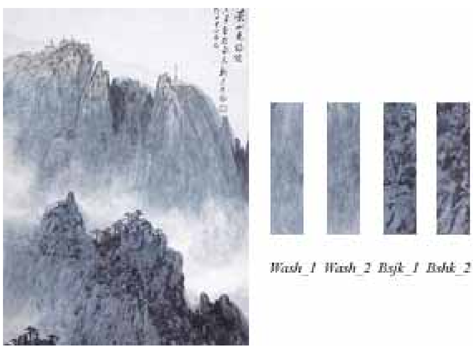
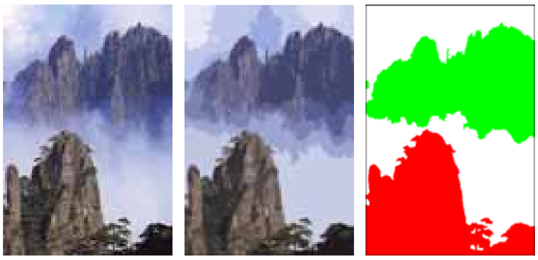


Fig. 4. A Chinese landscape painting and BSTP collected from it

We choose different kinds of brush stroke texture images from the background mountain, middle ground mountain (if possible) and front ground mountain as BSTP, namely *Wash*, *Bshk, etc*, Fig. 4 shows a Chinese painting and a few BSTP collected from it. In order to avoid noticeable repetition of the BSTP that may appear on the final rendered image if multiple BSTP are used, we usually choose two or three texture images for each kind of BSTP, which are then called randomly by the system in the mapping phase.

4 Control Picture

In a typical Chinese painting, Chinese artists usually draw multiple mountains. With our rendering scheme (described in detail in Sections 5~8), we need to recognize different mountains so that the system can call corresponding BSTP in the mapping phase and provide location information for fog image synthesis. Our solution to this problem is to construct the control picture with mountains painted by different colors as their ID, as shown in Fig. 5 (c).



(a) (b) (c)

Fig. 5. Construction of the control picture

The control picture can be constructed either manually or semi-automatically. In the manual fashion, the user paints the control picture according to the application, say, the shapes given by the art director in animation production. Compared with hand-made Chinese painting where individual brush strokes must be drawn carefully to present the texture of the mountains, the control picture is much simpler to paint using existing painting system such as Photoshop and CorelDraw *etc,* and the detailed texture can be added by our system during the on-line sessions. If users wish to convert photographic images or video sequences into Chinese painting, they can take the semi-automatic fashion, that is, constructing the control picture by first processing photos or video sequences with NPR filters, the "cutout" filter in the Photoshop for instance, and then painting the mountains in different colors using flood paint tool in existing painting systems, as shown in Fig. 5 (c).

In our system, we use red, blue and green colors to identify the foreground, middle ground and background mountain respectively. In the case of more than three mountains are painted in a panting, we require the user to group them for the foreground, middle ground and background by painting them with appropriate colors.

5 Shading Picture

Chinese painting is a highly abstract art form, and artists don't make realistic use of tone, lighting and naturalistic color when painting objects, but rather prefer to shade object in a simple way to express their "deep feelings" regarding the painted objects.

For aesthetic purpose, we use a shading picture in the system to offer the shading that is neither realistic as in the photo no flat as in the control picture. The shading picture has the same shapes of mountains as those in the control picture, but the luminance values for the pixels inside the mountains may vary to suggest shading. Similar to the control picture, the shading picture can be constructed either manually or semi-automatically. In the later case we quantize the shades of the photo into a few luminance values and this can be achieved by applying the cutout filter in the Photoshop to the photographic image to produce the shading picture. From experiments we have found that 6~8 luminance values are adequate for our rendering task, and Fig. 5 (b) is an example of 8 luminance values.

6 Fog Image Synthesis

This section addresses the problem of synthesizing the fog by controlling fog density over the synthesized image. Unlike other still objects in the painting, fog may vary in its shape and density. To cope with these variations, we choose to use texture synthesis technique.

Several algorithms of texture synthesis have been proposed in the past few years and, based on the method given in [34], we introduce multiple seeds taken from the given sample as constraints to synthesize the fog image and the algorithm is illustrated with Fig. 6.

Given a sample fog image (left), in order to extract information of fog density varying downward as much as possible, we extract a number of vertical lines at equal distance in the sample image as *seed lines* and locate them in the synthesized region (right) as *seed constraint lines*.

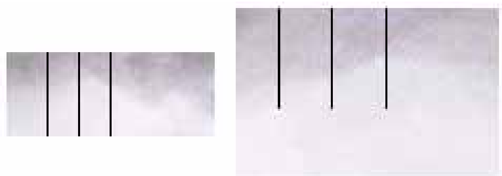


Fig. 6. Texture synthesis algorithm overview

To get an image looking similar to the sample with less computation on synthesizing, we usually take the seed lines every other two or three pixels on the sample image. For each seed constraint line, the synthesis process starts from its top to its bottom and grows a new image outward from these initial seed lines, one pixel at a time. To synthesize a pixel, we use the algorithm described in [34] to find all neighborhoods around its counterpart on the seed line that are similar to the pixel's neighborhood and then randomly chooses one neighborhood and takes it center to be newly synthesized pixel. Experiments showed that we could get impressive result for synthesizing the fog image if the window size is set 5x5, and Fig. 6 is an example.

For the fog surrounding mountains, our system first recognizes the color ID of the mountains, and then detects the points that draw the bottom lines of the mountains, finally takes them as the reference lines for placing seed constraint lines. In our implementation, we synthesize the fog image in a separate buffer and rise up the fog image so that it overlaps the lower part of the mountain (about 20% of the mountain height which can be calculated automatically by detecting the top and bottom lines of the mountain). After the BSTP are mapped onto the mountains, we use alpha-blending between the mountain texture and the fog image in the separate buffer in the synthesized painting, to make fog look transparent near the mountain and become denser downward.

For the clouds in the sky, we can use the same fog sample if possible to synthesize them by placing the seed constraint lines along the top edge in the final synthesized painting, and the luminance of the cloud image is controlled using alpha-blending to make it look brighter downward.

7 BSTP Mapping

The BSTP mapping phase consists of determining the number of BSTP, calling corresponding BSTP, BSTP processing and luminance control. We next present them successively in detail.

7.1 Determining the Number of BSTP

In most cases, the width of the mountain area to be rendered is bigger than that of a single piece of BSTP, thus we need to use multiple BSTP to cover the rendered area of interest. The number of BSTP required can be determined as follows: first, detecting the left and right extreme points of the mountain area with the proper color ID, and then calculating the mountain width covered by those two points, finally dividing the mountain width by the width of the

BSTP.

7.2 Calling Corresponding BSTP

In our system, the BSTP taken from the background, middle ground and foreground in the hand-made work must be called correspondingly to mach those in the control picture and this can be achieved through color ID provided in the control picture. To simulate the different painting techniques adopted by artists in dealing with the background and foreground mountain (as described in Section 3), we use single and multiple layers of BSTP correspondingly in rendering. With the color ID, the system calls proper BSTP automatically using the following procedure:

```
If (ColorID=GREEN) {
    Determing BNumGREEN:
    Call Wash_i randomly;
}
If (ColorID=BLUE or ColorID=RED) {
    Determing BNumBLUE or BNumRED:
    Call Wash_i randomly (First layer);
    Call Bshk_i randomly (Second layer);
}
```

where i is texture image index for each kind of BSTP. Above procedure can be changed with our interface according the requirement of the user, say, using single layer of BSTP for the middle ground with blue color ID if necessary.

7.3 BSTP Processing

For each paste operation, we first calculate the height of the region on the mountain to be rendered using the color ID, and then compare it with the length of the corresponding BSTP. If they are equal, the paste operation is applied, otherwise, we adjust BSTP length by either cutting BSTP shorter or adding a segment of BSTP taken from itself to its bottom, the perceptibility of seams is reduced by applying alpha-blending at the edge between the original BSTP and added segment.

7.4 Luminance Control

When the shading picture is used, we apply alpha-blending to the luminance of the BSTP using a blending factor k determined by the following equation:

$$k = RefLumi\ /BSTPAverLlumi \qquad (1)$$

where *RefLumi* and *BSTPAverLumi* are the luminance of the shading picture at the pixel of interest and the average luminance of the BSTP being used respectively. If the case of $k>1$ arises, we let $k=1$.

To deal with the luminance of two layers of BSTP used to render the foreground mountain, we blend the luminance of BSTP of the two layers using:

$$BlendLumi = \alpha * Lumi(Bshk) + \beta * Lumi(Wash) \qquad (2)$$

where *BlendLumi* is the blended luminance of the two layers, α and β are blending factors and $\alpha+\beta=1$. Our experiments show that α varies randomly between 0.5 and 0.7 corresponding to each BSPT would produce satisfactory results.

Before pasting operations, the BSTP of *Bshk* are converted to gray scales by the system, during the pasting operations, the luminance value of each pixel is calculated and only pixels with luminance values below the threshold can be pasted on canvas using equation 2. The lower threshold would yield more irregular shapes of strokes thus giving dry brush looks. With our interface, users can tune the threshold according the effect desired.

An advantage of using multiple layers of BSTP during the pasting operations is that we can blend BSTP taken from different paintings to get new styles and relevant examples are given in section 9.

8 Mountain Edge Rendering (*optional)

In hand paintings, some Chinese artists prefer drawing top edge of the mountains with thin brush strokes. To simulate those strokes, we first detect the top edge of the mountains of interest through color ID in the control picture, and then draw the edge with darker colors than those in the BSTP. The edge colors are perturbed randomly to get a handcrafted look.

9 Results

The architecture of our system offers flexibility for the construction of the control picture and the user can choose different ways suitable to his applications. The control pictures in Fig. 7 and 8 are obtained by processing photos. In Fig. 7, we use the BSTP collected from one hand made painting, while in Fig. 8 (construction of its control picture is shown in Fig. 5), we render the front mountain using the BSTP taken from the hand painting in Fig. 4 for *Wash* and in Fig. 9 for *Bshk*, respectively.

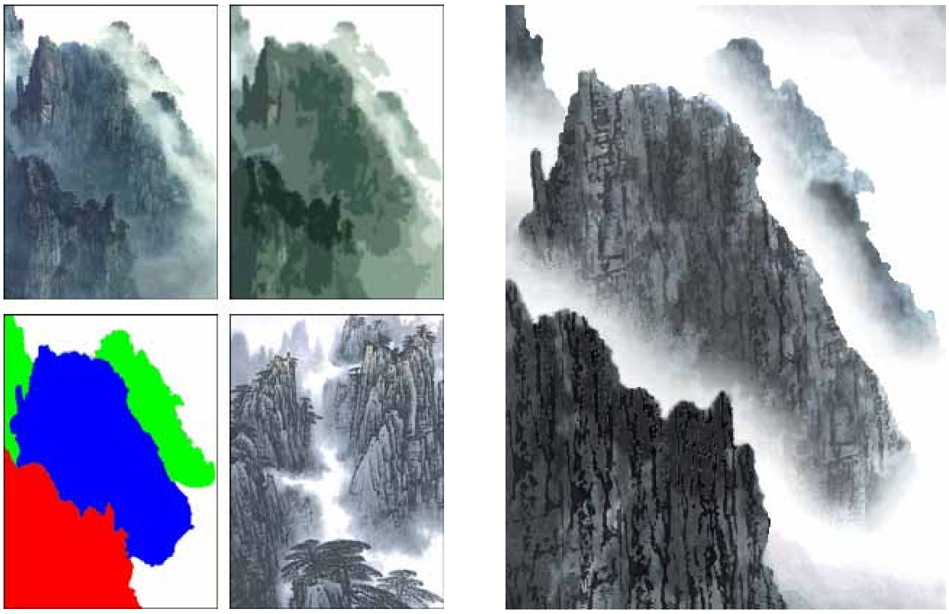


Fig. 7**.** The painting rendered by mapping BSTP taken from one hand painting

The control picture in Fig. 9 is painted manually. In this example, we use two layers of BSTP to render the background and foreground mountains and the orientation of the BSTP is controlled by rotating BSTP to proper angles before mapping.

The control picture in Fig. 10 is obtained by processing a hand made painting and, because of lack of space, the control picture is omitted. In this example we change the style of the original painting using the BSTP taken from two hand made paintings as shown at the bottom of the left picture in Fig. 10 to render the middle and foreground mountains respectively. The original painting (at the top of the left picture in Fig. 10) looks sun shin while the resultant picture looks rainy.

Changing the style of hand made paintings is significant in some applications such as animation, because we have numerous hand paintings that could be

Fig. 8. The painting rendered by mapping the BSTP from different hand paintings

used for the background in the animation. Those paintings would cause inconsistence of the style if used directly in the animation, and our system is able to convert them to the particular style desired as long as we use the same BSTP taken from the target paintings in the system.

Fig. 9. The example of painting the control picture manually

Fig. 10. Changing the style of a hand painting

10 Conclusions and Future Work

In this paper we present an approach for NPR to synthesize the Chinese landscape painting using BSTP taken from the hand-made work. We have demonstrated a rendering system with minimal intervention from the user. The system provides a tool for users with little training for the particular medium, enabling them to produce impressive images of nontrivial complexity. Potential applications of the system are generation of backgrounds with the style of Chinese painting in animation, education and entertainment.

The work suggests a number of areas for future investigations:

In the current implemented system, we use brush stroke texture image and "draw" a picture at the level of group brushes. It may be beneficial to use brush stroke primitive shown in Fig. 3 so that we can simulate the procedure of drawing a picture by a human artist at the level of individual brush.

Working with individual BSP relies on automatic brush stroke placement and the method described in [10] could be integrated into the system if the brush model is improved to produce more expressive effects.

It would be very interesting if the system is used in conjunction with a 3D geometric scene, thus we can generate a 3D landscape which looks of Chinese painting.

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基于图像合成中国画

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摘要：本文给出一个基于图像合成中国画效果的系统。该系统有两部分：首先从手工绘制的中国画图例中提取笔刷纹理图像并构建颜色控制图提供合成图像中各个山峰的 ID, 然后利用纹理合成技术生成云雾图像并通过控制图的 ID 把多层纹理图像映射到相应的位置上“画”出各山的形象。如果需要进一步表现山的明暗，则构建明暗图并在映射过程中控制纹理图像的明暗。文中给出合成的若干具有不同风格的中国画例子，其效果比现有模型方法更接近手工绘制的中国画。
关键词：非真实感绘制，基于图像的绘制，纹理映射，中国画.