Animating Water in Chinese Painting Using Autoregressive Model[*]

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Abstract: A method to animate water in Chinese painting is presented in this paper. This approach first detects positions of water forms in the hand drawn Chinese painting and synthesizes those forms using autoregressive model. Next, water forms are rendered using an image based rendering technique to produce water forms with the look of Chinese painting. Finally, water forms are animated in hand drawn environments thus the authors bring water forms in Chinese painting to life. The given examples demonstrate the capability of our method to capture the statistic properties associated with the sample data and to produce a variety of water forms for non-photorealistic animation.

Key words: water model; non-photorealistic animation; computer animation; Chinese painting

Traditional animators have experienced with various techniques for reproducing well known pictures on the screen thus creating animations far more sophisticated than those of animated cartoons. In the west, Alexander Petro is known for the rich, hand-painted look of his oil-on-glass animations such as The Cow and The Mermaid. Another example is Joan Gratz, whose lighthearted film, Mona Lisa Descending the Staircase (1992) deftly morphs through dozens of works of modern art including Picasso's nudes and Van Gouh's self-portraits, always maintaining a painterly quality thanks to her innovative "claypainting" technique. In the Oriental, Chinese animators produced a number of animations with the look of Chinese painting, which are famous in the traditional animation community.

Computer animation is only beginning to catch up to the variety of styles found in traditional and experimental animation. Non-photorealistic rendering (NPR) is a step in the right direction. Most of existing NPR techniques aim at creating still pictures and a few of them can be used to generate non-photorealistic animations such as impressionist painting[1,2], pen-and-ink[3], the style of Dr. Seuss[4,5] and Cartoon water[6].

Chinese painting as a traditional art form in China attracted many researchers to attempt to numerically model this beautiful medium using computer simulations[7~9]. Unfortunately, all of them focus on generating still pictures and little effort has been spent to animate objects with the style of Chinese painting. In this paper we present a method to animate water in Chinese painting. It is known that Chinese painting is created by use of four main tools including the ink brush, ink stick, ink stone and *Xuan* paper, and Chinese artists have long explored the richness of ink brush in a variety of styles. As a result, there are different visual interpretations of water in Chinese painting and

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Fig.1 gives a few examples [10,11].

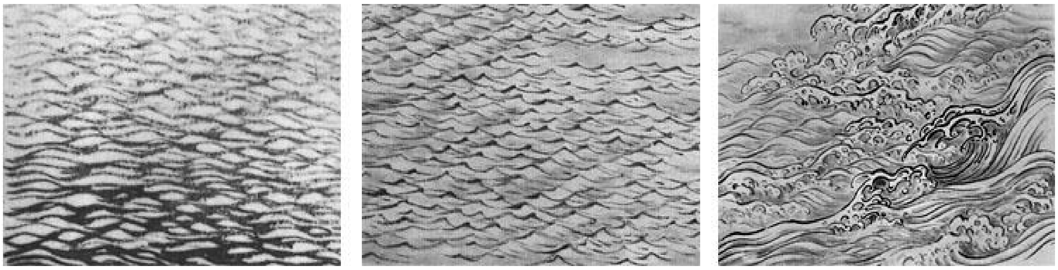

Fig.1 Examples of water interpretations in Chinese painting

After careful observation of those examples we can find that, due to slight shaking of the hand during the drawing process, those forms depicting water in the first two pictures are never repeatable in shape but look statistically similar on the whole, it is possible for us therefore to regard them as the outputs from stochastic processes. According to the theory of signal processing, those forms can be synthesized sing parametric methods of signal processing, say, signal estimation techniques (As for how to deal with water forms in the third picture in Fig.1 will be discussed in Section 4).

Parametric methods of signal processing are more appropriately called model-based methods[12], because each technique first assumes a pre-specified model set (e.g., all-pole, all-zero, *etc*) and then estimates the appropriate model parameters. In fact, the model-based approach consists of three essential ingredients: (1) data, (2) model, and (3) criterion. Once we select the model set, we “fit’ the model (parameter estimation) to the data according to some criterion. The parametric approach to signal processing is best summarized in Fig.2.

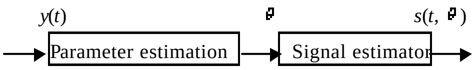

Fig.2 Parametric signal processing

Here we see that once the model set is selected, the estimator is used to obtain the unknown parameters that specify the model. The signal estimate is then constructed using these parameters. There are different techniques for signal estimation and we adopt the autoregressive (AR) model approach, in part because it is simple in structure and computationally efficient.

The remainder of this paper is organized as follows. In Section 1 we describe the estimation of AR model parameters using the data acquired from hand drawn water forms in Chinese painting. Section 2 addresses the main issues in water form synthesis, dynamic control and rendering of water. In Section 3 we give the results by showing a number of examples. Section 4 contains a brief conclusion and discussion of areas for future work.

1 Estimation of AR Parameters

The AR model is characterized by the difference equation for the input-output relationship

$$x(n) = -\sum_{k=1}^{p} a_k x(n-k) + e(n) \qquad n = 1,2,\ldots,N \tag{1}$$

where $e(n)$ is white noise with zero mean and variance, the are known as the AR parameters. The basic parameter estimation problem for the AR model is given as the minimum (error) variance solution to

$$\mathcal{E} = E\,|e(n)|^2 \tag{2}$$

where the estimation error is defined by

$$e(n) = x(n) - \hat{x}(n) \tag{3}$$

and $\hat{x}(n)$ is the minimum-variance estimate obtained from (1) as

$$\hat{x}(n) = -\sum_{k=1}^{p} \hat{a}_k x(n-k). \tag{4}$$

Note that $\hat{x}(n)$ is actually the one-step predicted estimate based on the past data samples, hence the popular name "linear predictor". The estimator can easily be derived by minimizing the prediction error; $e(n)$ obtained from (1) as

$$e(n) = \sum_{k=0}^{p} a_k x(n-k) \text{ with } a_0 = 1. \tag{5}$$

Minimizing (2) with respect to the AR parameters and substituting for $e(n)$ in the resulting equations, we obtain

$$\sum_{k=0}^{p} a_k g_{xx}(m-k) = 0,\ m=1,2,\ ..,\ p \text{ and } a_0 = 1. \tag{6}$$

where $g_{xx}(m)$ is the autocorrelation sequence of $x(n)$. These are called normal equations. The minimum mean-square prediction error is simply

$$\min g_{xx}(0) + \sum_{k=1}^{p} a_k g_{xx}(-k). \tag{7}$$

If we augment (7) to the normal equations given by (6), we obtain the set of augmented normal equations, which may be expressed as

$$\sum_{k=0}^{p} a_k g_{xx}(m-k) = \begin{cases} s_e^2 & m = 0 \\ 0 & m > 0 \end{cases} \tag{8}$$

where s_e^2 =minE for the AR random process. The equations can be solved efficiently by use of the Levinson- Durbin Algorithm[13].

One of the most important aspects in the use of the AR model is the selection of the order p, and much work has been done by various researchers on this problem. Experiment results given in the literature indicate that for small data length, the order of the AR model should be selected to be in the range $N/3$ to $N/2$ for good results, where N is the number of the sample data. In our case, the data sequence is usually acquired from the painting thus its length is not very long, we therefore adopt $N/3$ as the model order.

2 Water Form Animation

Water form animation involves the water from synthesis, dynamic control and rendering which are the topics of the following subsections.

2.1 Water form synthesis

The first step of water form synthesis is dada acquisition. Given a hand-drawn water in Chinese painting, we first detect some water forms using the snake algorithm[14] and then put them into arrays, say, *Form*(n)_*j* ($n \geqslant 0$, $j \geqslant 0$), where n is point index in an array and j is array index, respectively.

Once the data sequences are acquired, the relevant AR mode parameters can be estimated using the procedure described in Section 1 and water forms can be synthesized using equation (1) with the corresponding AR model parameters estimated.

The synthesized water forms *SynForm*(n)_*j* are actually sequences defined on 2D Cartesian coordinate system, where the horizontal axis is n. Those sequences can be used directly to draw water forms on the water surface where water is not moving. While for the moving water, water forms are usually drawn in the shape formed by the partially immersed objects such as rock, boat *etc* and the water surface, as shown in Fig.3. In this case, we need to devise skeletons using a few control points defining the shape required, and water forms (synthesized sequences) are drawn on these skeletons. Note that in order to make the resultant water forms look more natural, we draw the synthesized sequences in the direction of the flowing water, as show in Fig.4.

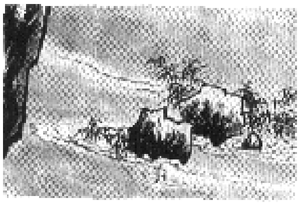

Fig.3 Waves near objects

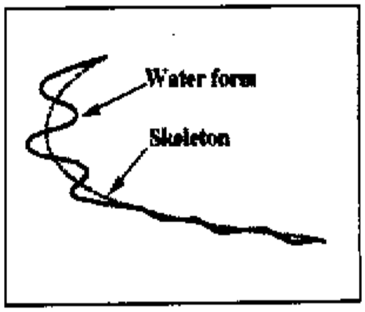

Fig.4 Synthesized wave over a curve

2.2 Dynamic control

Dynamic control of water forms aims at creating the illusion of the movement of the water. In the current hand-drawn examples, the movement of water forms is not very violent, thus, their dynamic behavior resemble very much to that of shimmering used in cartoon animation[15], which is a series of cels with varied interpretations of required style (as shown in Fig.5), the cels are then mixed one to another, at random, at the required speed.

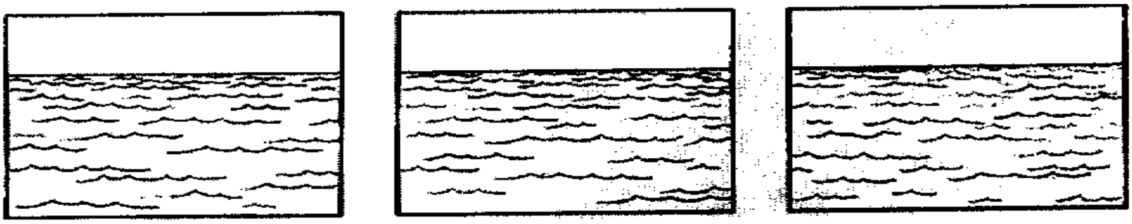

Fig.5 Shimmering

Note that, in shimmering, the interpretations of water waves are completely independent from one frame to the next that the frame coherence is maintained in the distribution of the massive interpretations rather than their individual shapes and dynamic movements. Inspired by the technique used in shimmering in cartoon, we adopt the fowling procedure to control water forms dynamically:

Initialization:

1. Specifying the mean value and variance for the length of water forms;
2. Specifying the density of the water forms;
3. Specifying horizontal distribution;
4. Specifying vertical distribution.

For frame t:

1. Generating a position *WtFormP* according to the horizontal and vertical distribution;
2. Generating a skeleton at length at *WtFormP* to control the length of the water form;
3. Synthesizing corresponding water form using the AR model;
4. Repeat those three steps until the density of the water form distribution is met.

End (of each frame)

2.3 Rendering

In order to generate water forms with the style close to Chinese painting, we use an image-based rendering technique which integrates our early work, a physically based brush model[16], with a different mechanism to generate the footprint of the brush with the look of ink brush.

Our early brush model makes use of particles within a circle or rectangle to form a *footprint*, a brush stroke is simulated by employing a skeleton to model the trajectory of the footprint together with a few *skeleton* attributes to control the *size* and *color* of the footprint, as shown in Fig.6. The color of each particle in the footprint may vary stochastically to generate a colored brush stroke.

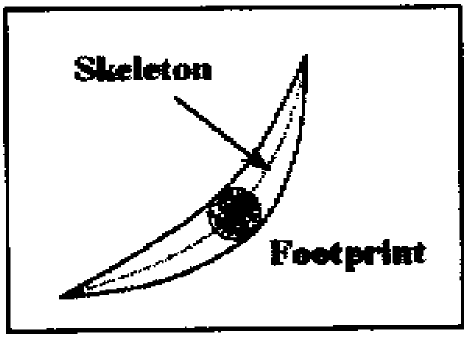

Fig.6 Brush model

Clearly, the texture of the footprint contributes very much to the final appearance of the brush stroke, hence, the distribution of pixel color inside the footprint is the key to determine the look of the stroke. To generate an ink stroke more realistically, we propose two image-based approaches to create the footprint. In the first approach, we color the particles inside the footprint using the color picked up randomly from the sample image of the hand drawn brush stroke, this approach is particularly suitable to generate a stroke with a mean color distribution. In order to cope with the variation of color along the trajectory of the stroke, we adopt an alternate approach described as follows.

First, we use the snake algorithm to detect some hand-drawn water forms and take the data describing those forms as the reference skeletons. Next, based on the skeletons, we subdivide hand-draw water forms into small segments from which a quadric polygon can be defined to cover the width of the water forms using a simple model. Texture inside each polygon is then mapped onto the desired water forms synthesized by the AR model. The mapping operation is repeated in succession for each polygon until the water form is covered fully.

3 Results

This section presents a number of examples of water animation with the look of Chinese painting.

Figure 7 is a frame of water surface animation emulating the first picture in Fig.1 by use of the sample data acquired from its hand drawn counterpart. In Fig.8 we show a frame of animation with a look close to the second picture in Fig.1. In comparison to water shapes in Fig.7 where several waves are drawn continuously, water shapes in Fig.7 are drawn in a “discrete” manner regarding individual waves (That is, the artist uses two brush strokes to draw each water wave). Thus, we cannot synthesize them directly using the AR model. Our approach to this problem is detecting positions of several water wave tips and putting them into arrays as the sample data, the sequences synthesized by the AR model are now used for controlling positions of water wave tips rather than for drawing water forms directly. For each tip, we first define two vectors starting from the tip and pointing downward to the left and right sides respectively with small perturbation added to their angles. Using the starting and ending points of each vector we can generate a slightly bend skeleton by adding a control point below the vector, the skeleton is then used to draw ink stroke using our brush rendering technique.

The first picture in Figs.9 and 10 show two hand drawn environments and we animate water forms corresponding to that in Figs.7 and 8 by placing them locally near the objects above the water surface such as rocks, grass, boat *etc*, respectively. The animated effects look correct when we play back water series generated by our model.

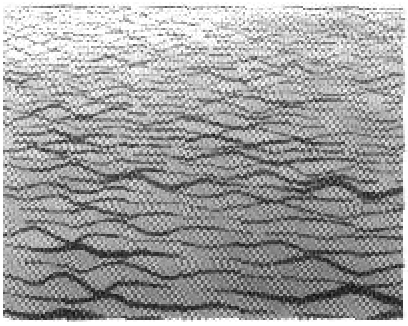

Fig.7 Computer generated forms

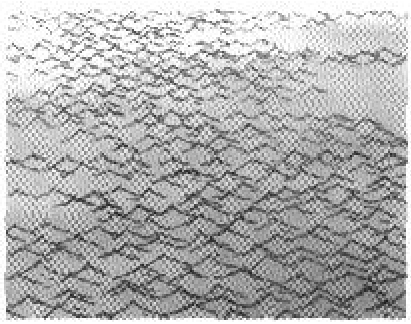

Fig.8 Computer generated forms

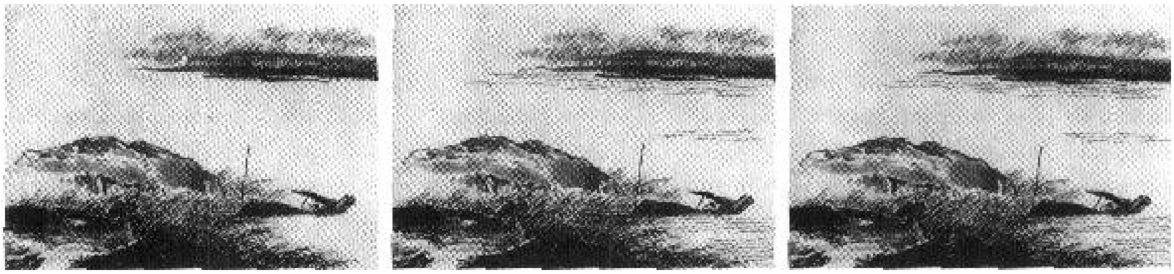

Fig.9 Animated water forms in hand drawn environment

Fig.10 Animated water forms in hand drawn environment

4 Conclusions and Future Work

In this paper we presented the results of research dealing with non-photorealistic water animation based on parametric signal processing approach. The advantage of this approach is that the AR model is able to capture the statistic properties associated with the sample data, thus we can produce a variety of water forms for non-photorealistic animation as long as provided with appropriate samples and shape visualization mechanisms in the system. Potential applications of our work are generation of backgrounds with the style of Chinese painting in animation, education and entertainment. In the current implementation, we animate only parts of hand painted pictures such as water forms. It would be fascinating if we animate not only water, but also other parts in a typical Chinese landscape painting such as rocks, trees *etc* in 3D. To achieve this goal, additional work need to be done for drawing other objects in 3D and this is a topic for future work.

As for shapes depicting caps in a more violent water movement as shown in the third picture in Fig.1, the AR model synthesis is not adequate for a faithful recreation of those forms, because some curves in the forms have multiple values for a given point on the horizontal axis, while the sample data and synthesized sequence in the AR model must be single value functions defined on 2D Cartesian coordinates where the horizontal axis is n.

Nevertheless, we are still able to synthesize the single value curve depicting the up contour of the caps and the other parts below it can be dealt with using fractal models. This is also a future research work.

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利用自回归模型生成中国画风格水动画

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摘要: 提出一个生成中国画风格水动画的方法.首先检测手工绘制国画水波的位置,然后利用自回归模型合成这些水波形状.合成的水波用基于图像方法来绘制以使水波与手工绘制国画风格一致.最后,将水波放在手工绘制的国画环境中运动起来构成动画.所附图例展示该方法能够获取手工绘制水波样本的统计特性而生成富有变化的非真实感水动画序列.

关键词: 水模型;非真实感动画;计算机动画;中国画

中图法分类号: TP391 **文献标识码**: A