On the Effects of Haptic Display in Brush and Ink Simulation for Chinese Painting and Calligraphy

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Abstract

In this paper, we develop an interactive haptic system, which can be further aid for digital Chinese painting. When an artist is holding our force feedback device, one feels like holding a real painting brush with all the contact and bending forces, since the viscosity, friction, and the bending force of a brush touching the paper are simulated. First we derive a physical dynamics model as bending springs for bristles to construct a 3D brush. Then we simulate the ink-water transfer system for ink spreading and color blending. Our system is a real-time system and users can interact with it holding a digital brush supported by either a Phantom force feedback device or a "WACOM pressure sensing pen" on a tablet. A pilot experiment was conducted, and the results show that brush writing with haptic feedback is better than that of same visual display but without haptic feedback.

1. Introduction

Strassmann developed Hairly Brushes [1] to simulate the traditional Japanese art known as *sumi-e*. Samples of position and pressure are interpolated as control points to form the stroke shape where pressure determines stroke width. Shi et al. [2] developed a tablet and a pressure sensing pen for a user to write calligraphic characters. A modification of brush touch pattern (footprint) was also proposed in order to simulate the proper shape of a stroke. Ip and Wong [3] use 2D-based rotated-elliptic footprint and ink depositing parameters to paint calligraphic characters. Way and Shih [4] propose a method of synthesizing rock textures in Chinese landscape painting, and the strokes are also 2D-based.

The methods used in the above researches can be generally classified as flat-brush-based approaches [5], which use 2D brushes of various shapes, sizes and patterns to form the desired stroke. On the other hand, there are also researches related to 3D brush model. Jintae Lee developed a bristles model for oriental black-ink painting. He uses a deformation model of bending bristles with one end fixed in a brush shaft keeping perpendicular to paper. Bill Baxter, et al. [6] use stretch springs as brush skeletons to deform subdivision surface. For the characteristics of Chinese brushes, certain feature in Chinese painting such as brush forking, is difficult to simulate by those two 3D methods. So we propose another brush bristle model, which is similar to Baxter's algorithm [6]. But we do not use stretch springs, instead, we use bending springs. We also design an eight-direction bristle model for real-time simulation.

For the haptic feeling, Baxter [6] uses SensAble Phantom device both as the input and output device. The force is related to the penetration depth, tilt angle, and velocity. Our haptic simulation is modified from Baxter's, while friction force is added. Furthermore we add a sensing distance to hint users when the pen is approaching the paper.

Figure 1: System configuration. A PHANTOM force feedback device is provided for users to draw the Chinese painting with haptic perception.

2. System Configuration

The proposed painting system consists of three parts: a force feedback device with 6 degrees of freedom (DOF), a 3D physical-based brush model plus a paper model, and a model for ink and water transfer. With force feedback, a user experiences the interaction between the pen and paper and one can feel more realistically. The painting system derives the position, orientation, and force information from the 6 DOF force feedback device to complete the simulation. The brush model is constructed by using physical-based springs as the skeleton of the brush. The springs used in this system are not stretch springs as in most related researches; instead, the proposed system utilizes springs which adopt bending angle as the control variable. In the real world, bristles will not change their length when they are pressed. Therefore, bristles are more like bending springs rather than stretch springs. By using the information retrieved from the 6 DOF device, the brush model changes its position and orientation and simulates the shape it represents. Then, the detection of collision between the brush and paper is performed. Furthermore, the shape, orientation, position of brush, as well as volume of ink and water contained in brush determine the stroke drawing on paper. In the meantime, force information is sent back to the force feedback device to simulate the feeling that user touches a paper. Lastly, the ink-water transfer model is responsible for the transfer of ink and water in brush and paper.

3. 3D Brush Modeling

Figure 3 is the 3D bristle models. In the left, they are model A and model B where the hair should be vertical but in actual use, the water condensing force keeps all hair in a cone shape. And we put nine bristles in eight directions in the brush model as the skeleton in bending simulation.

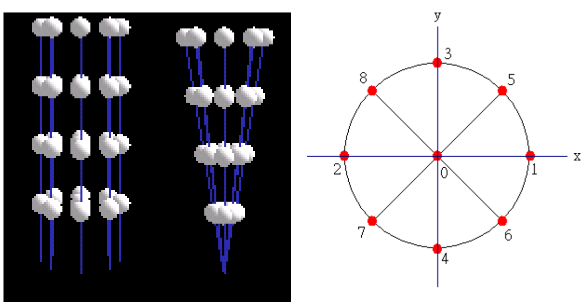

Figure 2: The 3D bristle models.

4. Ink-water Transfer Simulation

Our proposed system adopts a multi-layered structure to simulate the transfer between ink and water. We also simulate the flow of water and ink on the surface of paper. Such kind of movement is related to the amount of water and ink. It is also related to the fiber structure of Lee's paper [5].

5. Haptic Simulation

In the stage of haptic simulation, the force output function should be carefully designed. If the output function is not a continuous function, there will be vibrations or buzzes from the motor of the haptic device. Those will distract the user's attention when one crafts his painting.

Another important issue is about the haptic update rates. It is better to update the force in about 1k Hz or more. So the force function should be calculated as simple as possible. The philosophy of haptics programming is, force feedback module should be small and fast, and graphics rendering and processing will take more time, so they should be split.

When the brush approaches the virtual paper, we would like to provide haptic hints to the hand. Furthermore, friction coefficient is related to the surface property between brush and paper. Since our brush may have different ink and water in different time, we slightly modified the simulated friction.

6. Experiment Design and Results

Our system had been used for more than seven artists. Some painting results by our system are in figure 4 (in the color page). With our haptic simulation, users are more satisfied and enjoy the fun of painting.

In order to know whether the haptic feedback in writing is useful or not, we have designed an experiment to verify our hypothesis. The hypothesis is that (method A) brush writing with haptic feedback and visual display of brush is better than that of (method B) visual display of brush only.

As a pilot study, six subjects are used, all of them are undergraduate students of Dept. of CSIE, National Taiwan University. Method A and method B were randomized in sequence, and were given to subjects to write a Chinese character "forever(永)". After the test, the subjects were asked to use a pencil to check which method is better in achieving this simple task, whether it is method A or B.

The results show that four out of six subjects select method A (with haptic feedback) over method B (without haptic feedback). In order to be significantly different, and to corroborate our initial hypothesis, another full scale experiment is under development, and the final report will be given later.

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Figure 3: Painting Demo. The demo shows the bending bristles and ink-water transfer. The left side is color pigments selection area. The painting brush can touch pigments to pickup and to mix the color.

Figure 4: Sample paintings done by Huei-Ling Chiou, Babylon Tian, Joe Lian, and Sory Wang.