Simulating Chinese Brush Painting: The Parametric Hairy Brush

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1 Introduction

In Chinese brush painting each stroke exists on its own as a piece of art. The distinct characteristics of a brush stroke come from the combination of a painter's skill with the unique physical properties of the paper, ink, and brush. As an artist paints the brush bristles deposit ink and water on the paper, the ink and water diffuse through the paper, and the bristles deform due to external forces.

Digitizing the painting process requires a solution to three distinct problems: modeling ink and water diffusion in paper, modeling soft brush dynamics, and creating a stroke input method. Recent research demonstrates that solutions to the latter two problems are more fundamental for capturing the style of Chinese brush painting [Chu and Tai 2002]. Until recently, however, nearly all research has focused exclusively on the first problem. The Parametric Hairy Brush (PHB) is a new brush model designed to realistically simulate the Chinese brush. The two key properties that distinguish the PHB from previous brush models are a simple and flexible geometric representation of the internal structure of a real brush and the ability to simulate a wide range of stylistic effects "out of the box" without manual configuration of esoteric parameters.

2 Design and Results

The PHB represents the brush with a control volume (Figure 1: left) similar to the NURBS solid found in [Xu et al. 2002] defined by using a line, ellipse, and two circles – all centered on a Bézier curve – as sweeping profiles. Within the control volume, individual bristles are represented as Bézier curves defined by two tangent vectors. The first tangent vector has a fixed length and tail position located within the circle at the brush base. It points roughly parallel to and away from the brush handle. The second tangent vector starts at a point on the line and goes through a point within the ellipse. The line is parameterized by one variable (l) and the interior of the ellipse is parameterized by two more variables (r, p). After calculating the dynamics for deforming the control volume, with an approach similar to [Xu et al. 2003], each bristle (b_i) is manipulated by adjusting the triplet $(l,r,p)_{b_i}$. The magnitude of the tangent vector at the end of the bristle is adjusted using an iterative convergence method to keep the arc length approximately within $\pm 5\%$ of its original length.

This model has several attractive properties: it is easy to satisfy relevant geometric constraints, simulation of a large number of bristles is fast, and the model provides a flexible framework for experimentation. The main geometric constraint of keeping the bristles above the paper is easily satisfied by exploiting the convex hull property of Bézier curves. A large number of bristles can be efficiently simulated since the cost of deforming the control volume is independent of the number of bristles while at the same time providing an approximate solution to how each bristle should be deformed. Lastly, after deforming the control volume, each bristle's position relative to the other bristles is adjusted by manipulating the corresponding triplet $(l,r,p)_{b_i}$. These adjustments finalize the approximate solution (Figure 1: center). Rules for updating the parameters are still being created based on experimentation. The existing rules can already model the tendency for wet hairs to clump together (by moving neighboring parameters closer) and for dry hairs to separate.

Initially the user input will be from a mouse or graphics tablet. The ideal input device, inspired by [Chu and Tai 2002], gives the feel of a real brush but features a far less intrusive data acquisition method. Using two orthogonally placed webcams to track the 3D position of two LEDs embedded in a brush handle an artist can input 5 degrees of freedom with the natural feeling of a real brush.[1] The position of the artist's hand is dictated by tradition, so the LEDs can be placed without fear of being occluded by the artist's hand.

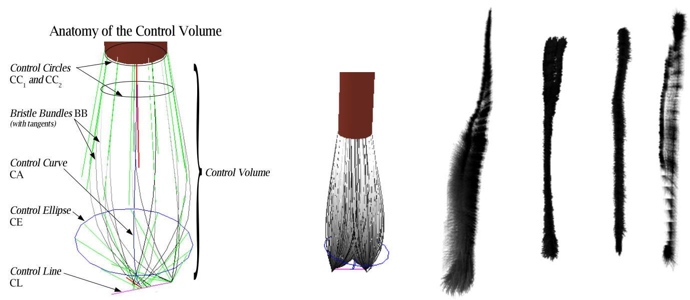

Figure 1: The anatomy of the control volume (left), an example of a tip split by setting all CL parameters to either 0 or 1 (center), and sample strokes written with the PHB (right)

Initial results (Figure 1: right) show that even without a sophisticated ink diffusion scheme the PHB is capable of producing aesthetically accurate strokes that possess a wide range of traditional stylistic effects. A commodity computer with accelerated OpenGL can easily simulate more than 1000 hairs in real-time. The input device is currently in the design phase and has not yet been implemented.

References

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[1]This input device was proposed by Giovanni Motta (e-mail: gim@ieee.org) in personal communications.