Brush up your painting skills

Realistic brush design for interactive painting applications

Abstract Most present-day interactive paint applications lack the means of adequately capturing a user’s gestures and translating them into realistic and predictable strokes, despite the importance of such a mechanism. We present a novel brush design that adopts constrained energy optimization to deform the brush tuft according to the user’s input movement. It incorporates bidirectional paint transfer and an anisotropic friction model. The main advantage of our method is its ability to handle a wide range of brush tuft shapes that are animated using a freeform deformation lattice, which is associated with the tuft’s geometry. This way, almost no conditions or limitations are placed upon the appearance of the brush. Examples range from round brushes modeled as polygon meshes, to flat brushes with individual bristles. Less common deformable tools that are used to apply or remove paint on the canvas, like sponges, can be created as well. The model is integrated in our interactive painting system for creating images with watery paint.

Keywords Paint systems · Physically-based modeling · Constrained optimization

1 Introduction

The paint brush is the medium that communicates an artist’s intentions onto the canvas. Its importance is pointed out by an experienced artist who states that “most of the materials involved in painting are expendable. Just about the only tools worth protecting are your paint brushes.” [24].

In digital paint applications the brush is equally important. As a subset of the “artistic rendering” research domain, which focusses on the creation of ‘pleasing’ artwork, the interactive paint applications emphasize the role of the user in creating painted images. In consequence, a 3D virtual counterpart of a real paint brush must be able to capture a user’s gestures and translate them to predictable strokes, while preserving a natural look.

Literature has already brought forward several models that target these issues, for both Oriental and Western paint styles. Most currently available commercial painting programs, however, essentially ignore the nuances in brush motion and still produce uniform, analytical marks. Given the numerous advantages of a digital equivalent of the real painting process, it is clear that an application that combines a canvas model that can capture complex paint behavior with an equally capable brush model would be a valuable tool for even the experienced traditional artist.
This paper presents a new brush model that complements our previously introduced canvas model [23]. It features the following characteristics:

– An efficient and general applicable method to deform the brush in real-time, using free-form deformation.
– Anisotropic friction.
– Bi-directional pigment and water transfer.
– Complex footprint generation.
– Integration in a real-time physically-based simulation framework for painting with watery paint media.

Unlike previously proposed solutions, our method does not use a skinning-based technique that concentrates on a single tuft shape, but relies on deformation of the tuft’s local coordinate system. This way, almost any geometry can be used to define its appearance, as shown in figure 1 and in the example section.

The rest of this paper is organized as follows: after discussing existing work on digital paint brushes in the next section, we first look at important characteristics of a real brush before introducing our own design. Different brush constructions with accompanying stroke examples are shown in Sect. 4, followed by conclusions and suggestions for future work in Sect. 5.

2 Background

In this section we look at how virtual paint brushes have evolved from being simple automated rubber stamp procedures, to versatile designs that generate realistic paint strokes and genuinely respond to an artist’s gestures. For extensive surveys on interactive paint applications, and nonphotorealistic rendering research in general, we refer to the literature [2, 8, 11, 19].

The work of both Greene [12] and Strassmann [22] can be considered as the starting point of a long line of attempts to create a more realistic means of input for paint applications. Greene describes an input device for turning a physical drawing action into a digital stroke, commonly referred to as Greene’s drawing prism [12]. Rather than trying to create a new brush model in software, this special device processes input from real brushes.

Strassman was the first to present a physical model of brush movement on a canvas with the purpose of creating traditional Japanese artwork using black ink [22]. The brush is modeled as a one-dimensional array of idealized bristles, each carrying an amount of ink. The actual creation of a stroke involves the input of a number of control points with position and pressure information from which the final stroke is rendered.

Virtual brushes have been considerably improved since the drawing prism and Strassmann’s one-dimensional version. The first physically-based 3D brush model was given by Lee, who adopted Hooke’s law to model a collection of elastic bristles [13]. This is one of many advanced brush models proposed in the literature, all intended for either producing paintings with Oriental ink or creating Chinese calligraphy.

In fact, only the work of Baxter et al. explores the use of virtual brushes in Western painting [1, 4]. The deformable brush integrated in their dAb painting system was the first to provide haptic feedback, enabling a user to actually feel how the brush deforms and therefore enhancing the sense of realism. A linear spring between the brush head and the canvas generates the forces that form the input for a PHANToM haptic feedback device. The dynamics of the brush head itself is handled by a semi-implicit method that integrates linear spring forces. These kinds of time-stepping integration techniques, however, are less suitable for use in a heavily damped system that is required to simulate the stiff bristles. Further limitations include the inability to handle bristle splitting.

Saito et al. introduce a more appropriate technique based on energy optimization [17, 18]. The function that has to be minimized captures the total amount of energy in the system, a summation of bend energy from joints, potential and kinetic energy from the tuft mass, and frictional energy. The result is a very stiff dynamical system where the static equilibrium is found almost instantly, which is a good approximation of real bristle behavior. The brush geometry is constructed by a single spine that is traced by a circular disc.

Several authors extended this technique. Chu et al. added anisotropic friction, lateral spine nodes to control brush flattening and a bristle spreading technique based on a static alpha map [6]. Their system also takes into account “pore resistance”, which occurs when bristles get stuck in irregularities of the canvas. Plasticity accounts for shape deformations by internal friction of the wet tuft, and is modeled by adjusting the target angle with a small value. The brush surface is again determined by an elliptical cross section that is traced along the spine.