FluidPaint: an Interactive Digital Painting System using Real Wet Brushes

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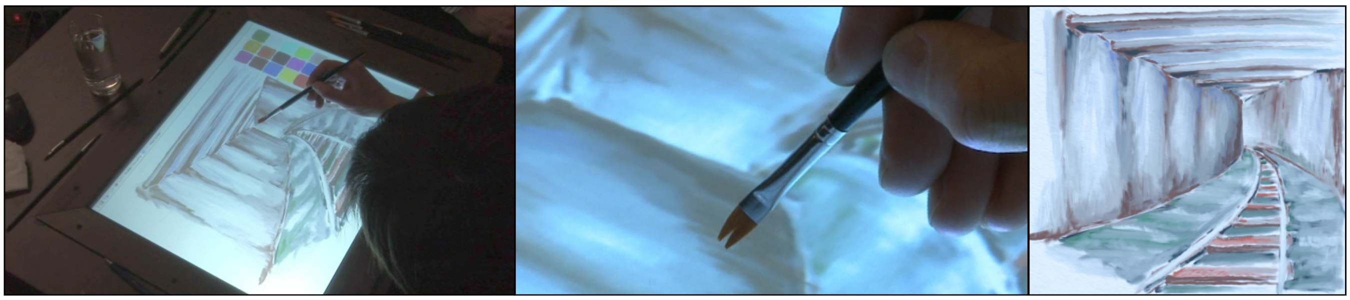

ABSTRACT
This paper presents FluidPaint, a novel digital paint system using real wet brushes. A new interactive canvas, accurately registering brush footprints and paint strokes in high precision has been developed. It is based on the real-time imaging of brushes and other painting instruments as well as the real-time co-located rendering of the painting results. This new painting user interface enhances the user experience and the artist's expressiveness. User tests demonstrate the intuitive nature of FluidPaint, naturally integrating interface elements of traditional painting in a digital paint system.

Keywords
Tabletop hardware, tangible UI, paint system, wet brushes

INTRODUCTION

Digital paint systems have evolved a lot in the past decades [6]. Although present systems do offer several interesting paint features (e.g., information saving, no paint dry time, undo of paint strokes), the user interface remains a major point of concern.

Digital paint systems have traditionally been using separate input and display devices for quite some time now. The use of dedicated input tablets leads to eye-hand coordination problems that, however, can be overcome by practice. And when integrated with an LCD display [9], there is still a considerable parallax between the digitizer stylus tip and the underlying LCD pixels. The stylus based painting also severely falls short in the actual user experience, even though virtual brushes can be equipped with properties of real brushes (e.g., size, shape, friction, rigidity). The different kind of friction, the point-based input, the lack of correct force feedback and the visual absence of a brush shape remain major usability issues and cause cognitive load for the user. If digital painters were able to trade the digitizer stylus for a real brush, several of the aforementioned usability issues could be resolved. However, in order to take full advantage of the brush, the digital paint system should provide accurate tracking of the contact surface of the brush with the digital canvas.

This paper presents a novel digital paint canvas, which allows for accurate registration of the actual contact surface of a real brush with the paint canvas, as well as the shape and direction of the bristles in the brush tuft in this contact surface. The paint canvas has a thin transparent top surface that virtually eliminates the visual parallax between the brush/canvas contact and the display surface. The paint canvas provides for a co-located input surface and display area, and offers water-based paint friction.

In the next sections the new paint canvas technology is described. We then discuss its integration in the digital paint environment FluidPaint, a hybrid paint system that combines advantages of both traditional and digital painting. In closing we present the results of a small user experiment.

RELATED WORK

Several recent touch sensitive surfaces allow for brush detection, although the quality is very coarse and low.

Multi-touch systems based on [3] consist of a thick transparent layer (~1 cm acrylic) with total internal reflection of infrared (IR) light. Touching the layer frustrates the total internal reflected IR light, which can be captured by an IR camera. When a diffuser screen for projection is positioned under the transparent layer, the thickness of the transparent layer blurs the image received by the camera. In this setup there also is an important parallax between the brush and the underlying image. When the diffuser screen is positioned on top, a compliant layer [3] (e.g. silicone sheet) is to be placed between the screen and the underlying transparent layer. When using real brushes, an unnatural large force has to be exerted in order to realize a mechanical contact through both the screen and silicone sheet to induce IR-light frustration. Hence these methods do not allow capturing a clear footprint of the brush, let alone the detailed bristle structure.

Microsoft Surface [5] is based on the IR image capture on the back of an IR illuminated diffuser screen underneath a transparent surface. Presence of real brushes can be detected, but only a blurred image of the brush is generated. It is also difficult to discriminate between real contact points and brush parts slightly hovering over the surface.

The Drawing Prism [2] is based on frustrating total internal reflection of light in a transparent prism. In this way the footprint of a wet brush can be detected by a camera. A significant difference with FluidPaint is the spatial separation between input and display device, leading to eye-hand coordination issues. Even if the prism shape were to be adapted to allow a back screen to display the painting result, this would result in an impractical setup as the screen would be located several centimeters below the interaction surface, resulting in an intolerable parallax. The user would also see the paint strokes some cm's below the contact surface of the brush, in a location that depends on the view position with respect to the prism.

Other approaches for brush footprint tracking revert to modifying the paint brush in some way. In the work of Iwai et al. [4] the thermal image of the footprint of a real brush dipped in hot water is tracked with an expensive far-IR camera. Besides tracking in low resolution, the use of the heated paint brush is also impractical. The IntuPaint system [7] uses electronic brushes with fiber bristles conducting infrared light to the fiber tips by total internal reflection. This system however requires the use of custom made battery-powered brushes, being unable to provide for the handling of real paint brushes and the artist's expressiveness with real paint brushes

THE NOVEL INTERACTIVE CANVAS DESIGN

Layered Structure

The operation of the new interactive canvas introduced in this paper is illustrated in Figure 1. It is composed of three layers, from top to bottom: the transparent surface layer, the diffuser screen and the transparent support layer.

The support layer provides mechanical stability to the canvas. The diffuser screen is used for the paint image display by means of back projection. The top layer is the actual painting surface and brush contact sensor. In order to minimize the parallax between brush tip and the underlying

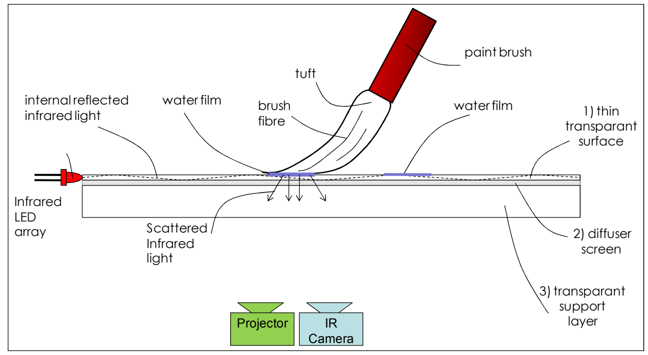

Figure 1. Concept structure of the interactive canvas.

image, the top layer must be very thin. IR light, emitted by IR LEDs placed next to the sides of the top surface plate, is propagated inside this plate by means of total internal reflection. No IR light escapes from the top or bottom of the plate.

Introducing Fluids

The contact of most day-to-day objects, including a dry paint brush, will only minimally frustrate the total internal reflection of IR light inside the top plate. This is due to the fact that most objects do not make enough optical contact with the transparent layer to propagate IR light out of the surface into the contact area of the object. Fluids like water and "sticky surface" materials like silicone can make good optical contact with the top surface, and allow the internally reflected IR-light to escape at the contact surface and propagate further.

In the proposed FluidPaint system, wet brushes are used for realizing good optical contact. The IR light propagating through the water can reach the bristles of the brush, resulting in light reflection in several directions. This IR light is an image of the brush footprint and can be captured with an IR camera located under the canvas.

Figure 2 shows the IR footprint image of a dry brush A and a wet brush B, both in contact with the top layer. The image generated by the dry brush A is very weak in comparison to the image of the wet brush B. The footprint of the latter is clearly visible, as well as the contact intensity in different locations.

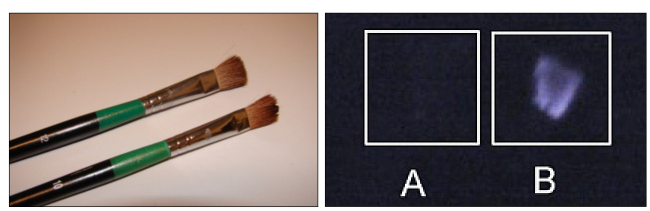

Figure 2. Left: dry brush A (12mm) and wet brush B (10mm) Right: the corresponding IR footprints.

The IR light will also propagate into residual water left after painting strokes on the canvas. This is illustrated by the "water film" to the right of the brush in Figure 1. However, as the residing water immediately spreads horizontally, the entering IR light will be internally reflected again at the water/air interface and remain propagated inside the top surface.

The use of water (or other fluids) for painting has several advantages. It clearly discriminates between "contact" and "non contact" of the wet brush with the canvas. Even small paint brushes only slightly touching the canvas give an IR footprint signal. Hovering brushes or touching dry objects are not detected. The use of wet brushes has the additional advantage that the brush tuft and its deformation tend to behave more like a real brush filled with paint. The wet contact interface is also similar to the contact interface when painting with real paint.

The paint canvas also permits the use of other wet input means, like fingers, sponges or tissues. Sponges or tissues can be used to e.g. create special effects or to erase paint.

FLUIDPAINT, THE PAINT PLATFORM

Prototype Setup

A prototype system, FluidPaint, has been realized. The active screen area is 45cm x 35cm. The top transparent surface is 0.6mm thick polymethyl methacrylate (PMMA). This transparent plate is illuminated by 160 infrared LEDs of 950nm wavelength equally distributed on all four sides of the canvas. For correct operation, infrared light needs to enter at the side of the plate and must propagate further by total internal reflection. Therefore a LED setup has been made such that the LEDs can be adjusted in height to exactly enter light in the side of the plate.

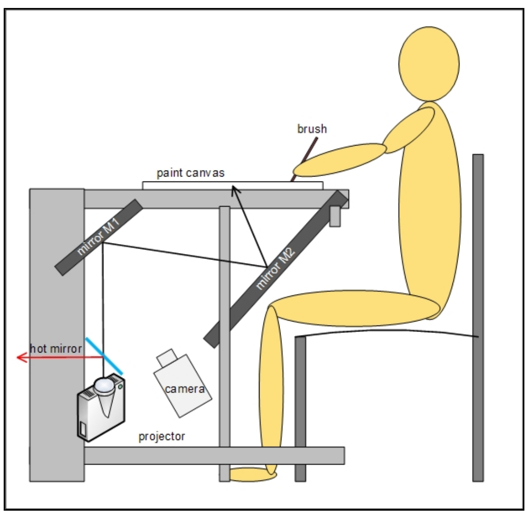

Figure 3. The setup of FluidPaint.

The support layer consists of 8mm PMMA. To prevent parasitic infrared light signals, the introduction of infrared light in the transparent support plate has to be avoided. The interactive canvas has been integrated as a paint canvas in a small mobile desk, as illustrated in Figure 3. A Sanyo PLC-XU100 LCD projector with XGA resolution is used for back projection. The paint surface is placed horizontally. In order to reduce the size of the system, mirrors M1 and M2 fold the optical path of the projector. The projector is pointing upwards to the mirror M1. A hot mirror is placed in front of the projector in order to filter IR-light from the projector. The angle of the mirror M2 with the painting desk provides a convenient position for the user at the paint desk. A 1624x1224-pixel PointGrey GRAS-20S4C camera, equipped with a Sony ICX274AQ 1/1.8" CCD and a 950nm IR band pass filter, captures the frustrated IR light from brushes in contact with the paint canvas.

Software and User Interface

The prototype setup has been completed with model-based paint simulation software, based on work by Van Laerhoven et al [8]. The paint software runs on a desktop PC (Intel Core2 Duo CPU E6750 @ 2.66GHz, 2 GB RAM, Windows XP, nVidia GeForce 9800 GT2) and is GPU-accelerated.

The graphical user interface of FluidPaint is presented in Figure 4. The paint canvas (about 35 by 35 cm) is situated on the left hand side. On the right hand side, there is (from top to bottom) the color palette, the brush cleaning area (with yellow sponge texture), the brush color indicator and a color mixing area. The brush color indicator shows the user what colors have been soaked in the virtual brush tuft.

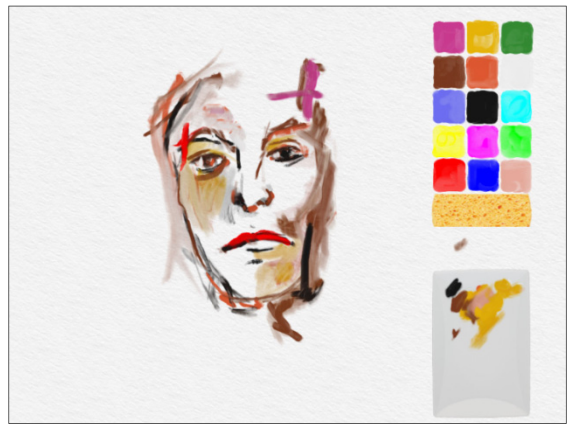

Figure 4. The user interface of FluidPaint.

The paint brushes are kept wet by dipping them in a small water reservoir, next to the paint canvas. Loading paint is as in traditional painting: stroking the brush in a repetitive way on a color in the color palette.

The video camera captures images at a resolution of 1280x960 pixels at 25 frames per second (fps). This is a trade-off between image resolution and image capturing speed. Tests demonstrated that 25 fps is quite acceptable, also because the paint simulation software is able to interpolate between tracked footprints. In the current setup, FluidPaint offers a footprint tracking resolution of about 70 dpi, which suffices to capture the bristles of the brush. This also permits to register the nuances in brush strokes, which is important to render realistic paint results.

FluidPaint aims at improving the user experience of digital painting by constructing a hybrid physical/digital paint platform. The key elements to achieve this goal are the use of traditional paint brushes, a simple and intuitive user interface, accurate brush tracking, the use of a fluid and a realistic paint simulation. While the first two elements strongly support the concept of embodied interaction [1], the precise brush tracking and the realistic paint simulation could also enhance the paint experience. In order to get a first assessment of the usability of the new paint setup, a small user experiment has been organized.

USER EXPERIMENT

Setup

The target audience of FluidPaint is twofold. The platform is primarily targeted at digital artists, possibly tempted by the use of real brushes in a digital platform. FluidPaint might also persuade traditional painters to have a go at digital painting, because of the user interface similarities with regard to the traditional paint environment.

Therefore two traditional and two digital painters, all being amateur painters, participated in the user experiment. The test participants were allowed to work on one or two subjects of choice for about two hours. Afterwards the participants were asked to fill out a user questionnaire.

Results

All participants were quite positive about FluidPaint. They found the user interface intuitive and experienced it as rather familiar. Being able to paint using real brushes came as a great surprise to all test participants. They all valued being able to see the actual shape and tufts of the brush, as it helped them considerably in painting accurately. The tracking of the brushes was evaluated as quite precise. One painter mentioned that after painting for a while, the perception of actually painting with real paint emerged.

The use of water was not considered disturbing, well on the contrary. Three participants indicated the water actually added to the familiar feeling whilst painting. The need of loading water regularly from the reservoir was picked up quickly, although the frequency was rather low in comparison to loading paint on the color palette. The small water drops that gradually started residing on the paint canvas during the experiment were not experienced as a problem.

The seating position was experienced as quite comfortable. Three participants suggested a slightly tilted surface to enhance the perspective view and the overview on the painting. The paint canvas was unanimously judged to be sufficiently large. One artist suggested reducing the brightness of the LCD projector behind the paint canvas. The rendering speed of the paint simulation was generally experienced as being sufficiently fast. The degree of realism of the paint simulation was considered quite good, as demonstrated by the artworks in Figure 5.

CONCLUSION

In this paper FluidPaint, a digital paint system using a novel interactive canvas, is presented. FluidPaint allows using wet brushes on co-located I/O displays with minimal parallax, while tracking the actual brush footprint with its real tuft deformations with considerable detail. FluidPaint therefore enables a new paint experience and opens up new ways of expressiveness for artists in digital painting, previously impossible with existing systems.

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Figure 5. Some artworks by the test participants.