Bi-Brush: Painting On and Using Small Touch Devices as Dynamic Brushes with Interactive Displays

ABSTRACT

We present Bi-Brush, a novel technique allowing users to sketch on interactive displays using a small touch device as a paintbrush. Not only does Bi-Brush provide a user-engaging drawing experience that is suitable for a broad audience, it enables a rich painting process with dynamic brush parameters controlled both by the built-in sensors the touch display of the tangible device. We describe a proof-of-concept prototype of the technique and report results of a light-weight qualitative evaluation, which show that the drawing experience to be enjoyable and that users are able to create compelling visuals.

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: User Interfaces

General Terms

Sketch-based Design

INTRODUCTION

Painting, drawing and sketching is a ubiquitous form of creative expression, be it to communicate ideas through visuals, share artistic illustrations, or simply doodle thoughts. The considerable differences between traditional painting and digital painting with a mouse has long been a barrier to creative and fine-controlled sketching on computers. However, the practice of digital painting has drastically increased with the release of graphic tablets, tablet computers and small touch devices, that offer a more engaging and direct interactive experience on digital supports.

Most drawing applications running on tablet computers — that users can carry everywhere—are typically designed for quick and simple sketching. As such, they are often limited to the most primitive drawing tools, confining users to a rough and rudimentary style. Conversely, graphic tablets—that typically sit on a desk—aim to offer a richer pen-like experience, by controlling pressure and orientation of the digital pen. These, however are typically employed by professional software, where brush types and many of their parameters can be fine tuned through a complex graphical user interface. Such systems, although offering the best flexibility, can be difficult and intimidating for new users to learn, and thus discouraging for novice or casual users.

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In this paper, we explore the use of small touch devices as reconfigurable brushes for digital painting on interactive displays. We propose *Bi-Brush*, a novel technique designed to support an engaging tangible-input painting experience through the flexible control of brush parameters with the interactive affordances of the device, namely its accelerometer and touch display. Bi-Brush, thus allows simultaneous drawing at two levels: with the device as a brush on an interactive display, and directly on the device's display to dynamically control brush stroke parameters and appearance while drawing. The position of the brush stroke on the interactive display is captured as the position of the tangible touch device, and like digital pens, the built-in accelerometers of the small touch device define brush orientation.

After a brief review of the related work, we describe the design rationale Bi-Brush has been built on. We then discuss technical details of our prototype implementation, followed by a light-weight evaluation. Finally, we conclude with a discussion of future avenues of research.

RELATED WORK

Stylus-like use of small devices with touch sensitive displays has been widely explored in the literature. For example, Hardy *et al.* [1] have proposed a technique allowing users to pair a mobile device with a display and perform selection by using NFC/RFID tag grid. Along similar lines, PhoneTouch [7] refines the selection by correlating the accelerometer data and the surface input. By installing an optical sensor, CornerPen [4] explored using a smartphone as a digital pen for making input on itself or other external devices.

There exists a large body of research on digital painting systems. FluidPaint [8] allows artists to paint with real wet brushes on a transparent surface illuminated by infrared LEDs. Other tangible brushes involving a more advance hardware have also been proposed. A self-illuminated LED brush whose bristles are made of semi-transparent nylon fibers has been proposed in [9]. I/O brush [6] provides the means to picking colors of real-world objects with a tiny camera embedded inside the brush. Otsuki *et al.* [5] developed a mixed reality painting system that allows users to paint on both 2D and 3D objects using brushes with magnetic sensors. Recent research by Vogel *et al.* [10] proposed a conté like input device enabling easy mode switching using its different corners and faces, e.g., paint colors, when interacting with tabletop surfaces. In most of these systems, the brush property settings are associated with the drawing display using graphical widgets that need to be reached, and if controlled concurrently while drawing, distract user focus from the drawing task. Furthermore, all the above devices require specific hardware, which are not as ubiquitous as small touch devices.

THE Bi-Brush DEVICE

Design guidelines

The design of Bi-Brush is motivated by the following guidelines for an effective tangible device to serve as a brush for digital painting on interactive displays:

Small footprint: The device should be lightweight and small enough for comfortable manipulation as a brush.

Portability: The brush device should not be tethered or tied to a specific setting or environment, to be equally usable on different interactive displays without additional reconfiguration.

Prevalence: The device should not consist of specific hardware to support the broader audience of users.

Proximity: The brush and stroke settings should be attached to the device itself, in order to facilitate dynamic adjustment of brush parameters while drawing, and to prevent split attention due to distant access to a graphical widgets on the drawing display.

Personalization: In order to accommodate various users' styles and preferences, the device should allow for the storage and loading of presets, facilitating the management of personalized brush configurations.

Mode Switching: The digital device should allow easy switching between different modes, to provide as many interaction types as possible (e.g. the brush functionality can be used in drawing as well as erase mode).

Based on the above criteria, we believe that small touch devices, such as smartphones, are ideal candidates for our purpose. Indeed, almost everyone owns such devices, making potential brushes prevalent and personalized.

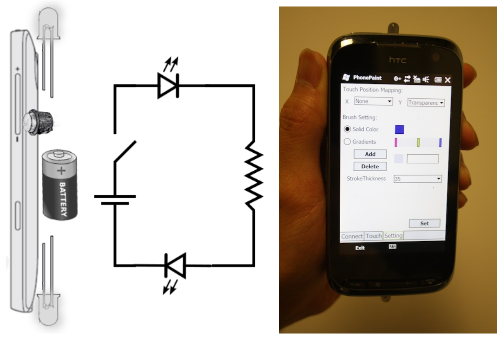
The touch display can be used as a dedicated interface for controlling parameters on the brush itself (e.g. a settings panel made of sliders and buttons). Finger manipulation on the display can also offer two extra degrees of freedom (x and y coordinates) for varying brush properties in real-time, e.g., stroke width, color hue and opacity, while drawing strokes with the device on an interactive display.

Moreover, most of these generic devices are equipped with additional built-in sensors that can be used for controlling brush interaction while drawing. For example, tilt angles interpreted from the accelerometer data can be mapped to transparency gradients of the drawing colors (with the metaphor that only part of the brushes bristles' makes contact with the drawing surface), provides an experience that is closer to working with a physical brush.

Unlike the ordinary stylus for painting, our tangible digital brushes can benefit from additional features usually supported by small touch devices, such as inter-device communication, data transfer and camera capabilities, as follows:

Data Transfer: Settings and resulting sketches can be fluidly transferred between the brush and the interactive display (or other devices) to support easy sharing and record.

Outside World Communication The digital camera can collect additional input from the world environment (e.g. using real-world imagery as a color or texture palette [6]).



(a) (b)

Figure 1. The Bi-Brush implementation on the phone

Proof-of-Concept Implementation

Based on the design goals, we created a research prototype using a HTC Touch Pro 2 phone as the Bi-Brush brush and a Microsoft Surface as the painting display. The phone and the surface communicate via Bluetooth. In this exploration stage, we chose to implement features that are critical for the painting process. Features such as data transfer and camera usage, secondary to our goal, are left as future work.

The Phone

In order to make the footprints of the phone detectable by the surface, we attached two infrared LEDs (5mm diameter, 1.2 V) to the back of the phone (Figure 1-a). One LED was used to track the device in the drawing mode, and, when the phone was flipped, the second LED was indicated the position of the eraser. The power of two LEDs was supplied by an AA battery. A customized system was developed in C# language for configuring the brush parameters and sending data to the surface through the wireless network.

Figure 1-b shows the UI configuration of the software, in which the user can set the color and the linear color gradients of the brush, basic brush width, and the mapping of finger touch positions on the phone display, to brush parameters such as stroke transparency and stroke width. In addition, the phone accelerometer data was used: 1) to compute the tilt angles for changing the brush opacity gradients perpendicular to the stroke drawing direction, and 2) to distinguish whether the brush was in drawing or erasing mode, when the corresponding LED was in contact with the surface. While this prototype only implemented associations of sensor data with a few drawing parameters, other parameter mappings can be easily added in a similar fashion.

The Painting Surface

The Microsoft Surface was raised to a height of 30cm to allow users to comfortably reach the full surface of the display, when standing beside it. Since an important affordance of Bi-Brushis to incorporate the brush settings directly on the brush device, the interactive display itself is simply a drawing canvas. The surface, thus, only receives data sent by the phone, and interprets the brush parameters to render strokes, using the tracking information of the phone footprint coordinates. To facilitate the evaluation of Bi-Brush, we developed a simple UI as shown in Figure 2, which we will discuss in detail below.

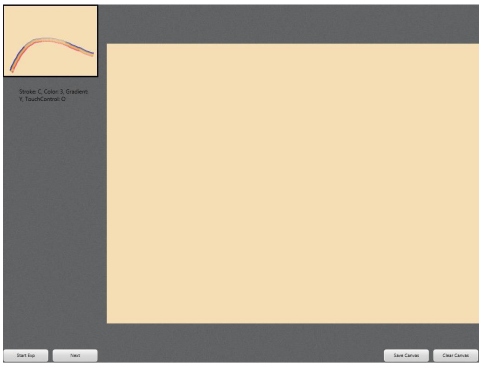


Figure 2. The sketching software UI on Microsoft Surface

EVALUATION

We conducted a light-weight evaluation of Bi-Brush. The purpose of this experiment was to gather qualitative feedback from users and study the usability of Bi-Brush.

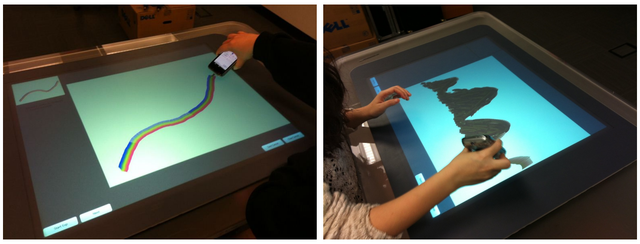
Five volunteers (3 females), aged 22–31 participated in the study. Participants were members of the University community (graduate students and researchers), all right-handed and with no prior professional artistic training.

A system built as described in the previous section was used for the study. The HTC Touch Pro 2 has a 3.6 inch display (resolution 480×800 pixels). The dimensions of the phone are 116×59.2×17.3 mm and its total weight (including the attached battery, LEDs and so forth) was 195g. The Microsoft Surface used in the experiment had a 30 inch display with a resolution of 1024×768 pixels.

Before the experiment began, the experimenter gave a brief introduction of the Bi-Brush concept and demonstrated the use of the hardware and software. The participants were then invited to perform 5 minutes of free-form painting as practice to get familiar with the environment.

The experiment consisted of a sequence of 24 trials where subjects had to reproduce, on a blank canvas, the example stroke shown at the top-left corner of the display (Figure 2). Textual instructions were provided under the example sketch, describing the conditions required for completing the trial, including the general shape of the stroke, the number of brush colors, whether using phone tilt angle to vary brush opacity gradients or not, and what brush parameters should be controlled using the touch display.

Subjects were asked to reproduce a similar stroke to that shown in the example sketch following the textual instructions (Figure 3-a). The manipulation of various brush properties (e.g. colors or width) was encouraged as long as the required instructions were obeyed. Subjects could restart the trial as many times as they desired until satisfaction. No time limit was imposed. Trials could be committed and advanced by hitting the "Next" button at the bottom-right corner of the surface. After completing all the trials, participants were given 10 min. for free-form painting (Figure 3-b), after which they filled out a post-study questionnaire and an informal short interview about general feedback of the technique. The whole study lasted about 30 min.



(a) structured drawing time (b) freestyle drawing time

Figure 3. A participant during the experiment

Figure 4. Examples of free-form sketches performed by participants

The conditions of the experiment were: 2 stroke types (straight line or curvy line) $\times$ 2 color modes (single solid color or three color gradient) $\times$ 2 opacity gradient modes (with or without phone tilt to change brush opacity gradients) $\times$ 3 touch display control modes (not using the touch display, and using touch position to change brush transparency, or brush width) = 24 conditions. In the experiment, participants performed all the experimental conditions without repetition, i.e., 24 trials in total.

RESULTS AND DISCUSSIONS

We observed that participants were able to familiarize themselves with the system after a short practice time and then complete the tasks fluidly with little assistance on setting the brush parameters. Most trials were achieved fairly quickly (about 30s). Trials that required the use of the touch display while changing the phone tilt angle were more time-consuming (about 50s).

Subjects sometimes performed several attempts to get the best results on a trial. In the free-form drawing period (10 min), several talented participants were able to create compelling sketches (e.g. Figure 4). Some even requested more time to finish their artwork. Overall, participants considered the whole drawing process to be fun and engaging, and reported that they really enjoyed it. Particularly, they liked the use of the tilt angle to change opacity gradients, since "*with this [she] can draw fancy strokes by just rotating [her] wrist*".

Our post-study questionnaire contained six questions which participants were asked to rate on a 1-5 Likert scale (the higher score, the better). Figure 5 summarizes the results. The reactions to the system were relatively enthusiastic. Participants generally thought it was flexible and compelling to control multiple stroke parameters in real-time ($\mu = 3.8$) and they were eager to have such an application on their own phones ($\mu = 4.4$). We observed larger variances on question four ($\sigma = 1.0$) and question six ($\sigma = 1.1$). These

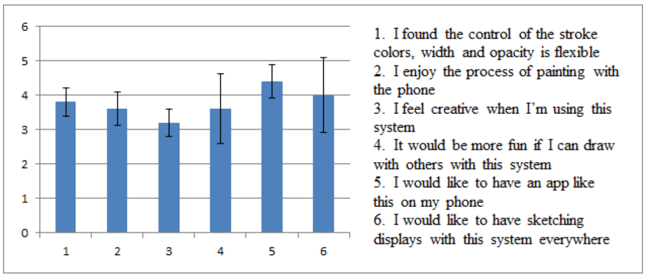


Figure 5. Questionnaire results

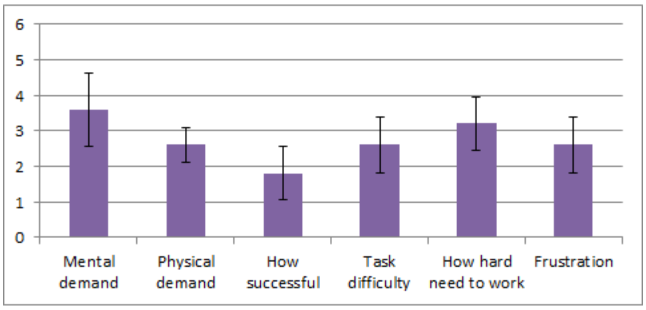


Figure 6. TLX-based questionnaire results

questions relate to the collaborative aspect, that could be explained by differing preferences. We also included a six-question TLX-based questionnaire [2] (the lower score, the better). Results are showed on Figure 6. While the tasks were demanding, both cognitively and physically (in part due to the simultaneous control of many degrees of freedom of the brush), participants generally considered their performance as very successful.

The experiment allowed us to identify several usability issues. Participants found it difficult to use the touch display for parameter control while brushing using only one hand. Although none of the participants had recourse to using their second hand on the touch screen, such an approach could overcome this issue (a similar interaction can be found in [3]). One participant suggested that "*a physical slider or button could be better than a touch display*". Haptic feedback could indeed provide a better sense of the state of the settings, however, we argue that touch screens are more flexible in accommodating various UI configurations, and do not require specialized hardware.

From the setup point of view, the weight of the phone is heavier than traditional brushes and participants reported this can become cumbersome and tiring for sustained use. Finally, high precision sketching is difficult to achieve because of 1) the noise and coarse resolution of data captured by phone sensors such as the accelerometer and 2) the occlusion of the phone body when sketching very fine strokes. Such fine drawing tasks tend to be rare in the typical sketching done by non-professional artists.

CONCLUSIONS AND FUTURE WORK

We have introduced Bi-Brush, a technique designed for informal sketching, which allows users to directly paint on interactive displays with their handheld touch device as a paintbrush. Bi-Brush aims at improving the users' experience of digital painting by allowing for the control of brush parameters by interacting with the brush itself.

There are a number of future directions along this line of research. First, more functionalities can be added, for example the features mentioned in this paper including picking attributes of real objects by using the phone camera and transferring data between the brush and other devices. It will also be interesting to explore other interaction techniques in our context to improve the overall user experience. One possibility could be enabling vibration feedback to convey additional information about the current brush settings.

Our current prototype only supports single user painting on the surface at a time. We plan to extend the system, to support multiple brushes at a time by associating the phone IP address and contact IDs on the surface (each time the phone starts to contact the display). Further evaluation of the system on both collaborative and individual footing should also be conducted to better understand the capabilities of this medium. Although further study is required, our prototype suggests that Bi-Brush enables a broad audience of users to combine small touch devices and display surfaces in a novel way, for casual ubiquitous sketching.

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