Figure 1

Participant using intangibleCanvas to finger-paint on a non-planar, digitally-projected canvas. The sensor lies in direct line-of-sight between the user and the projection, allowing for embodied, visually connected interaction.

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intangibleCanvas: Free-Air Finger Painting on a Projected Canvas

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Abstract
With the advent of new sensing technologies, precision free-air interaction is becoming viable as a contender for the next generation of expressive, embodied interaction modalities. ZeroTouch [5], a novel multi-touch sensor that allows for free-air multi-finger, multi-object sensing, is one example of this next generation of free-air interfaces. We develop its use in a digitally-projected finger painting application, placing the see-through multitouch sensor in direct line-of-sight between an artist and a remote canvas. This allows the artist to reach through the sensor and paint on the intangibleCanvas as if it were directly in front of them. An iPad is employed as a multimodal workspace for color selection. We evaluate the system through an informal walk-up-and-play installation and comparative study, developing implications for interaction design using this type of precision free-air interface.

Keywords
Artistic Composition, Free-Air Interaction, Embodiment, Multi-Touch, Multimodal Interaction

ACM Classification Keywords
H.5.2. User Interfaces: Input Devices and Strategies

General Terms
Design, Human Factors

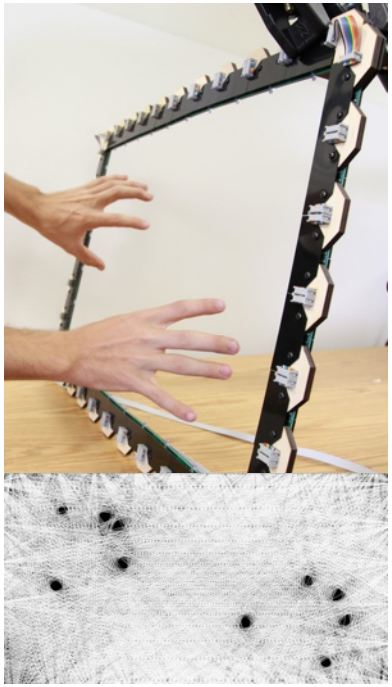

Figure 2

ZeroTouch sensor in action. Any objects inside the sensor frame are visualized as black blobs. The resulting image is processed with standard computer vision techniques to identify and track the position of these blobs.

Introduction

Free-air gestural interaction is a hot topic in interaction development with the release of consumer-grade hardware like Microsoft Kinect and other motion-tracking technologies. New sensing technologies like these allow for free-air gestural sensing at low cost. In time, these interfaces will increase in precision, enabling sensing of individual hands, fingers, and other objects.

ZeroTouch [5] is a recent development in precision free-air interfaces, enabling the sensing of multiple objects (fingers, hands, styli, etc.) within a given interaction plane. It works by turning on individual infrared LEDs along the perimeter of a frame, and then using a dense array of sensors located along each edge to detect light from the LEDs (Figure 2). Given enough LEDs, a 2-dimensional visual hull of the objects inside the sensor frame is generated, which can then be detected using standard computer vision techniques.

This project explores the use of free-air interaction in creating art on large, digitally projected canvases. Recent developments in free-air interactive digitally projected art include MobiSpray [7], an interactive art tool in which artists use cell phones to spray digital graffiti onto a surface. Laser Tag, a Graffiti Research Labs project [1], accomplishes a similar task using laser pointers and computer vision instead of cell phones.

Rather than use a physical implement imbued with sensors, such as an iPhone or Wiimote, we use the unique affordance of the ZeroTouch sensor to enable visually connected, embodied interaction with a remote canvas. By placing the sensor in the direct line-of-sight between the artist and projected canvas (Figure 1), the artist can finger paint with the *intangibleCanvas* (intangible as there is literally no touching involved).

Compared to vision-based free-air interaction systems like CavePainting [3] or Helma [4], where 3-dimensional interaction is use to create 3-dimensional drawings, our system is constrained to interaction within a specific two-dimensional plane.

We then evaluate the intangibleCanvas system through two user studies, and develop implications for free-air, visually connected interaction design. Our strongest finding indicates that proper feedback is essential in designing effective interaction with precision free-air interfaces.

Design Process

Our design process involved 2 expert interviews to help us understand the methods, both practical and conceptual, used by typical artists. Our first interviewee was an architecture professor who teaches composition at the undergraduate level. Out of the three compositional styles she conveyed to us: conceptual, analytical, and expressive, we chose to focus on expressive composition. An expressive composition focuses on expressing an idea or a feeling, as opposed analytical (e.g. a floor plan) or conceptual (e.g. diagraming) representation.

To further refine our ideas about expressive composition, we interviewed a professional artist about his artistic process and methodology when creating expressive works. He emphasized the importance of color selection and blending in the context of expressive art. As paint is a subtractive media, colors

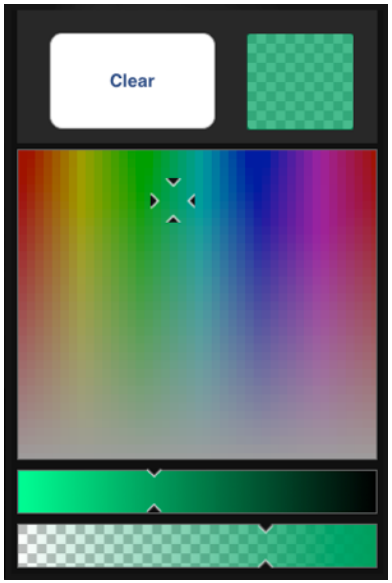

Figure 3

iPad Digital Color Palette.

Offers hue and saturation selection via the 2-dimensional color palette, and value and opacity selection through horizontal sliders.

blend together to form new colors. For intangibleCanvas, which uses an additive color space, enabling the artist to control color selection and opacity blending would be crucial to enabling effective expression throughout the interaction.

To this end, we chose to develop a multimodal solution for color selection: an iPad application that acts as a digital color palette. In addition to providing precise control over color and blending, it maintains the finger painting metaphor, differentiating by interaction modality the process of color selection from the process of applying color to the intangibleCanvas.

Prototype Development

After conducting our initial investigations, we developed a prototype of our proposed system to more thoroughly explore the actual experience of using such a system.

ZeroTouch Picture Frame

Our first step was adapting the ZeroTouch sensor to the application we had envisioned. Because ZeroTouch sensors are constructed from a number of individual sensor modules, it is reconfigurable into many sizes and shapes. To further reinforce the idea of painting on an intangibleCanvas, we arranged the ZeroTouch modules around a picture frame (Figure 4). From the user's point of view, the frame appears to be an empty picture frame. By putting his hands, fingers, or other objects inside the frame, he can paint inside the intangibleCanvas, while seeing the output through the frame on the projected surface. This creates a sense of embodiment not present with a visually disconnected interaction, like a typical graphics tablet.

iPad Digital Color Palette

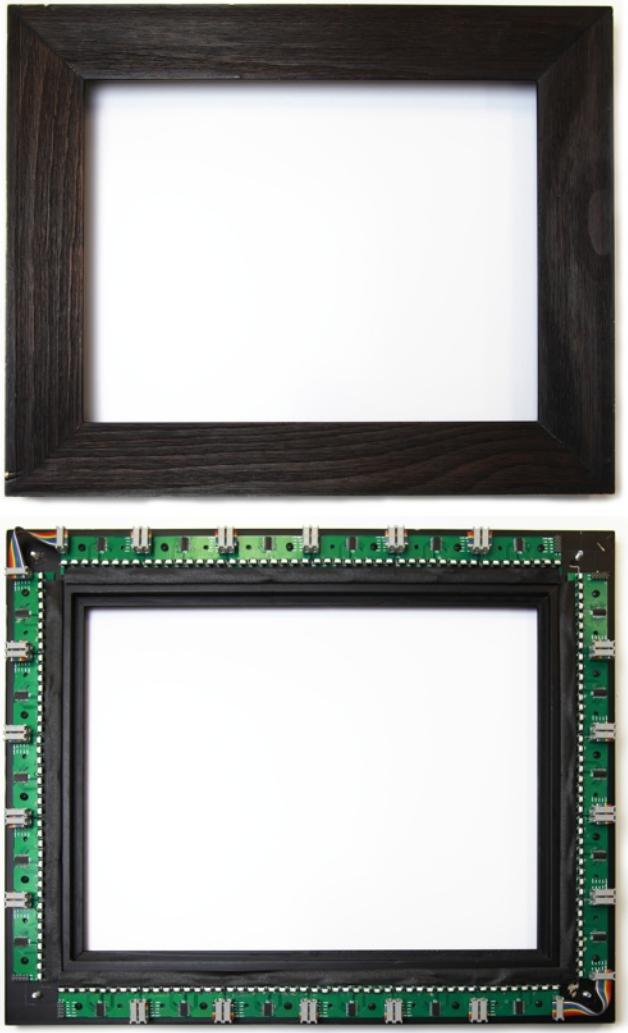

Figure 4

Front and back view of ZeroTouch Picture Frame.
Interior dimensions of frame are approximately 11" x 14"

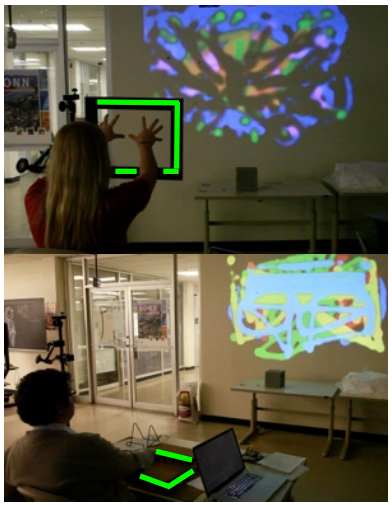

Figure 5

Comparative user study conditions.

Free-air condition on top.
Tabletop condition on bottom.
Sensor location highlighted in green.

To enable effective, expressive use of color in our system, we employ an iPad as a digital color palette. The iPad application communicates via wireless OSC to the paint application, and allows users to select hue, value, saturation, and opacity through a simple touch interface. A clear button allows the user to clear out the canvas to work on a new composition. The color selection app is a modified version of the HUE open source iOS application by Vevent, Inc.

PyMT Finger Painting Application

To implement the finger painting application itself, we modified a multi-touch painting application bundled with the open source PyMT multi-touch framework [6]. All UI elements were removed from the program so that input from the ZeroTouch picture frame is only used for painting strokes. ZeroTouch communicates with the PyMT finger painting application over the common TUIO protocol [2].

Evaluation

Prior to the development of the iPad color palette application, and shortly before conducting a comparative study, we set up the intangibleCanvas system as a guerilla installation in the foyer of the architecture building to gather initial feedback on the system and gauge user interest. The 17 participants were allowed to play with the system for as long as they wished, optionally filled out a short questionnaire, and occasionally conversed with us about the system.

While the users found the system interactive, playful, and fun, they wanted more control and more features. They wanted to be able to change the stroke style, brush size, color, and blending options. They also wanted the ability to draw straight lines and simple shapes, something that proved difficult given the nature of the interaction.

A complaint in our initial investigation was the lack of tactile feedback from the sensor. There were multiple occurrences of users unintentionally drawing extraneous points because parts of their hand, other than the intended finger(s), were passing through the ZeroTouch picture frame, activating the sensor.

Comparative User Study

Without yet solving the tactile feedback problem, we pressed on with development of the iPad color palette and ran a more in-depth user study, comparing the visually connected, free-air interaction with a tabletop condition, where the sensor and the display are visually decoupled, to elicit insight into the differences between the intangibleCanvas medium, and that of a traditional graphics tablet.

We compared conditions within subjects in a comparative user study. Everything was exactly the same across conditions, except the location of the ZeroTouch sensor. Both conditions can be seen in Figure 5. The iPad was used in both conditions to control color selection through the interface shown in Figure 3. The order in which the interfaces were presented was alternated between users.

Seven participants were asked to engage with the system for at least 5 minutes in each condition (though many spent longer), then answered a short questionnaire about their experiences.

Based on the questionnaire responses, we found that the free-air condition is more engaging and more fun, but the tabletop condition is easier to use.

Five out of seven participants rated the free-air condition as both more fun and more engaging. All but one participant indicated that they felt more connected to their composition in the free-air configuration, the outlier feeling equally connected with both conditions.

Five out of seven participants also found the tabletop condition easier to use. The majority said this ease was due to the tactile feedback of the table against the finger.

All participants stated that using the iPad color selection was easy, or very easy, and almost all agreed that they were able to effectively express themselves with color in the composition. The use of this second interaction modality clearly enabled the participants to effectively use the system.

Implications for Design

We develop implications for free-air interaction design. First, activation threshold feedback lets the user know *when* the sensor will be activated. Pre-activation positioning tells the user *where* the sensor will be activated. Next, visual/physical connectedness creates a sense of engagement by mapping body movements to system responses. Finally, for multimodal interaction design, avoid splitting attention across modalities.

Activation Threshold Feedback

The free-air condition, while rated as more expressive and engaging, frustrated participants due to the lack of activation threshold feedback during free-air interaction. The tabletop condition on the other hand, did not suffer this problem, as the tactile feedback from the table enabled users to easily distinguish the activation threshold for the system.

This finding shows that feedback is important in free-air interaction scenarios where activation thresholds are ambiguous. While tactile feedback is difficult to achieve when dealing with free-air interaction (which is usually realized with computer vision), pre-activation feedback, i.e. letting the user know they are *just about* to cross the threshold, is instrumental in creating an effective user experience.

Pre-Activation Positioning

In addition to the need for activation feedback from the system, another common complaint that arose during the user studies was that it was too difficult to make precise marks on the image. Users were able to draw continuous lines with no issue; however, after lifting their fingers out of the frame it was difficult to go back to a specific location in the image. One solution to this is a two-layer sensor design, where activating the first plane, or hovering, visually targets a location on the canvas (a form of pre-activation feedback), and continuing through to the second plane actually activates the flow of paint.

Visual/Physical Connectedness

We found that participants felt more connected to their compositions in the free-air configuration. By giving the artist a direct visual connection between interaction and the projected space, intangibleCanvas connects the artist with canvas physically and visually. One participant said the system “made it seem as though my fingers were actually drawing on the wall”. Another

Figure 6

Simultaneous use of iPad color palette and ZeroTouch picture frame.

participant reported that the free-air configuration "helped me get into it more. It felt like I was directing the painting like a conductor". This is evidence that there exists a very physical sense of engagement due to the mapping between the body and system responses.

Avoiding Split Attention Across Modalities

Participants readily adopted multimodal interaction with the system. The iPad is well suited for use as a secondary workspace. However, most participants had to split their attention between drawing on the canvas and selecting colors on the iPad.

We observed only one participant engage in simultaneous interactions with the iPad and the ZeroTouch sensor (Figure 6). When interacting with both of the interfaces it is obvious that the visual focus of the participant had to shift between engagement with the canvas and color selection. Even the participant who engaged in simultaneous interaction had to split his visual attention between the two interfaces. As the main task at hand was composing on the canvas, it dominated the visual attention of users.

Conclusion

intangibleCanvas is an enlightening exploration into the types of interaction afforded by precision free-air interfaces. The biggest finding is the need for pre-activation feedback when using free-air interaction for precision control: without explicit feedback, controlled crossing of activation thresholds and precise positioning can be quite difficult.

That said, the visual feedback afforded by the see-through ZeroTouch sensor was enough for participants to rate is as more expressive than a traditional tabletop tablet drawing experience.

Additionally, we find that split visual attention is a common side effect when users are dealing with secondary workspaces such as the iPad digital palette. To enable simultaneous expression without splitting visual attention, alternative feedback modalities should be employed, or the interface should be designed such that it can be operated without looking.

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