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FROM GESTURE TO FORM: THE EVOLUTION OF EXPRESSIVE FREEHAND SPATIAL INTERFACES

Daniel F. Keefe, Department of Computer Science and Engineering, University of Minnesota, Minneapolis, MN 55455, U.S.A. E-mail: <keefe@cs.umn.edu>.

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Abstract

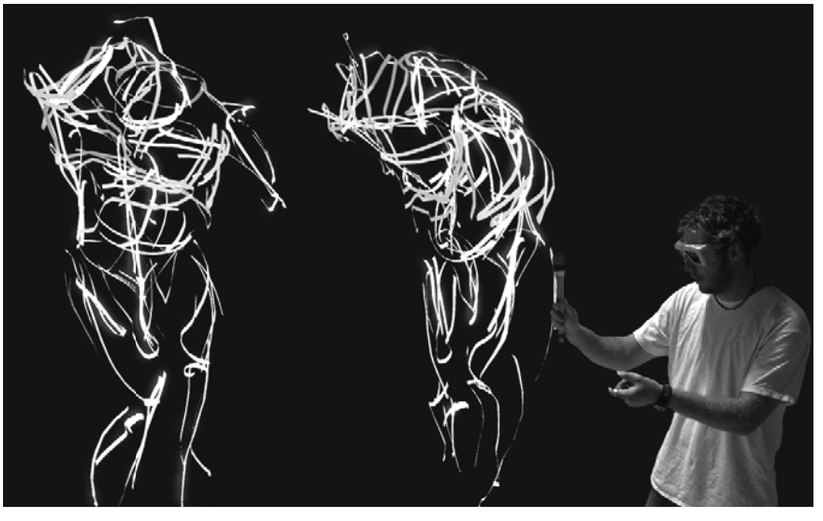
This paper presents a series of insights from an ongoing investigation into refining custom spatial computer interfaces and graphical primitives for suggesting 3D form in immersive digital spaces. Technical innovations utilizing 3D gesture capture, force feedback, and stereoscopic presentation are described through reference to specific free-form digital sculptures created with the CavePainting and Drawing on Air interfaces. The role of the human hand in digital art practice and the potential of interfaces that tightly couple freehand movements with geometric algorithms are discussed.

Over the past decade I have researched spatial human-computer interfaces both from a scientific perspective, motivated primarily by applications in scientific and medical data visualization, and from an artist's perspective, in my case driven by a curiosity to understand what it means to suggest virtual forms using visuals crafted from physical movement. This paper reflects on two milestones in these investigations embodied by digital works produced with the CavePainting and Drawing on Air interfaces (Figs. 1-3). I discuss how my thinking about creating rich mappings from human gesture to digital form has evolved through these investigations, and I describe a number of critical technical innovations that I researched in order to explore the new input and output spaces made possible by computing advances.

Throughout this effort, a consistent theme has been a desire to create digital works that not only utilize experimental algorithms and hardware, but also convey some evidence that the human hand is integrated into the creation process. In traditional media (e.g. painting, drawing, sculpture) we routinely draw upon the rich interactions inherent to the physical world as we push, pull, drag, brush, scrape, smudge, and smear pigments. Each of these actions leaves behind a fingerprint, a trace of the trajectory of the hand, or some other evidence or accident of the human maker. In contrast, as our capacity to collect and manipulate digital data increases, *creation* in digital media is increasingly defined through programming and adjusting algorithmic parameters, a process that leads to clean and exact representations, but generally lacks the spontaneity and richness of creation in the physical world.

Along with a number of like-minded artists [1,2,3], I believe expressive spatial computer interfaces have great potential to teach us how the physical and cyber worlds might coexist in the future and how future modes of digital creation might relate to current and previous art practice. Thus, a focus of my work to date has been building, refining, and then creating digital forms with new technical interfaces that draw inspiration from physical world actions.

Fig. 1. *Gesture Sketch*, two perspective views of a 3D model created using freehand movements tracked in space via the CavePainting interface. (© 2009 Daniel F. Keefe)



Capturing Freehand Gesture

Fig. 1 shows two perspective views of a 3D gesture sketch and a superimposed photo of me using the *CavePainting* interface [4]. CavePainting runs in an immersive virtual reality CAVE™ environment, where stereoscopic imagery is projected onto the walls of a 8x8x8 foot room using a perspective that updates in response to the artist/viewer's eye position. The experience of the head-tracked stereoscopic display cannot be captured via a photograph. Imagine walking through, ducking under, and reaching out to pass your hand through the 3D model shown in Fig. 1.

To create in this space, I wired a physical paintbrush prop with a button switch and a tracking device that reports the brush's position and orientation in 3D space to the computer in real time. When I push and hold the switch, the motion of the brush is recorded, and a virtual ribbon of form flows out of the brush as it moves through space. Thus, form is created directly through the 3D movements of my hand in space.

The shape of the virtual form emitted from the brush and the strategies for linking movement to form are almost unlimited. I have programmed and experimented with a series of 3D brush forms, including ribbons, various tube shapes, and animated splattering paint simulations, all of which respond to twists and turns of the brush in space. In the end, I find simple ribbon geometries (reminiscent of Picasso's light pen drawings [5] and Csuri's *Lines in Space* [6]) to be most effective because their simple shape accurately reflects the motion and intent of the hand.

The gesture sketch in Fig. 1 (perhaps better described as a 3D gesture model) is representative of the abstract ribbon forms I have created with CavePainting. The immediate mapping from movement to form makes it possible to introduce complexity into the scene through body-scale movements. I found that 3D brush simulations that are more "sophisticated" compared to the ribbons shown here actually masked my movements, hiding them within complex geometries that have an algorithmically dominated rather than kinesthetically motivated aesthetic.

As my experimentations with CavePainting became more refined, I became frustrated by a fundamental limitation of the technology. Without a surface and friction to support the hand, drawing controlled, deliberate curves in space is a tremendous challenge. This

Fig. 2. The Drawing on Air interface with mechanical pen force feedback device. (© 2009 Daniel F. Keefe)

limitation is less apparent in quick gesture experiments, but it is immediately obvious when working with more careful representational subjects.

Gesturing with Feeling (Touch)

The Drawing on Air interface [7] (Fig. 2) is an attempt to explore similar modes of freehand, digital creation with the addition of physically motivated force feedback. Again, I utilized a head-tracked stereoscopic environment, this time the size of a fish tank rather than a room. The key technical innovation is the use of the PHANTOM® force-feedback device (SensAble Technologies Inc.), which consists of a pen mounted on a robotic armature.

The PHANTOM device senses the position and orientation of the pen in space and is capable of exerting forces that I can feel while holding the pen. I programmed the device to provide several force-feedback cues. First, friction and viscous forces are applied to make moving the brush through the air feel more like moving through loose sand. Second, I developed a two-handed approach to drawing where I use my left hand to indicate a drawing pathway and then advance along this pathway by moving my right hand holding the brush. This method naturally lends itself to producing smooth, controlled curves; in fact it is inspired by "tape drawing," a drafting technique used to draw life-size smooth contours in automotive design.

Using the force-feedback device, I developed a 3D "line weight" control that makes it possible to adjust the thickness of 3D curves in space by pushing against a virtual drawing surface.

Fig. 3 shows two perspective views of *Swahili Bride*, a model I created working from a series of photographs taken in Tanzania. In contrast to the work in Fig. 1, notice the more deliberate placement of ribbons in space with careful attention paid to 3D placement, orientation (of the ribbon surface), and variation in line weight. Each of these elements has some analog in traditional drawing, thus the idea of suggesting form through their use is not new. What interests me most is how to do this in 3D digital spaces, where the *rich interactions* we rely on in the physical world (e.g. friction, pressure, contact) have no default meaning. In this case, I have reinterpreted a number of these traditional physical interactions to create a new, multi-channel mapping from physical motion to digital form.

Fig. 3. *Swahili Bride*, two perspective views of a 3D model created using the Drawing on Air interface. (© 2009 Daniel F. Keefe)

Working with "3D Line"

Both models (Figs. 1 and 3) use twisting 3D ribbon forms as a basic line drawing primitive. The most exciting aspect of these "lines" cannot be observed on the page—it needs to be experienced in a stereoscopic environment. When we view these tiny surface strips in stereo, walking and moving around them, our visual system receives additional cues that help us place the surfaces in space. This makes it very easy to mentally extend the path of a ribbon across hollow volumes in the form (i.e. negative space). As we walk around the form of the face in Fig. 3, for example, its volume becomes immediately understandable. In some cases, we can even see through the negative space on one side of the model to ribbons on the other side. I have found that these ribbon structures have a great ability to *suggest* 3D form.

In the future, I believe we will continue to see increasing connections between the physical and digital worlds. My hope is that a number of efforts in this direction, both in technology and in art practice, will successfully target interfaces that make it possible for us to link human physical expression with emerging digital spaces.

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