Drawing with the Hand in Free Space: Creating 3D Shapes with Gesture in a Semi-Immersive Environment

Steven Schkolne

Leonardo, Volume 35, Number 4, August 2002, pp. 371-375 (Article)

Published by The MIT Press

Drawing with the Hand in Free Space: Creating 3D Shapes with Gesture in a Semi-Immersive Environment

Steven Schkolne

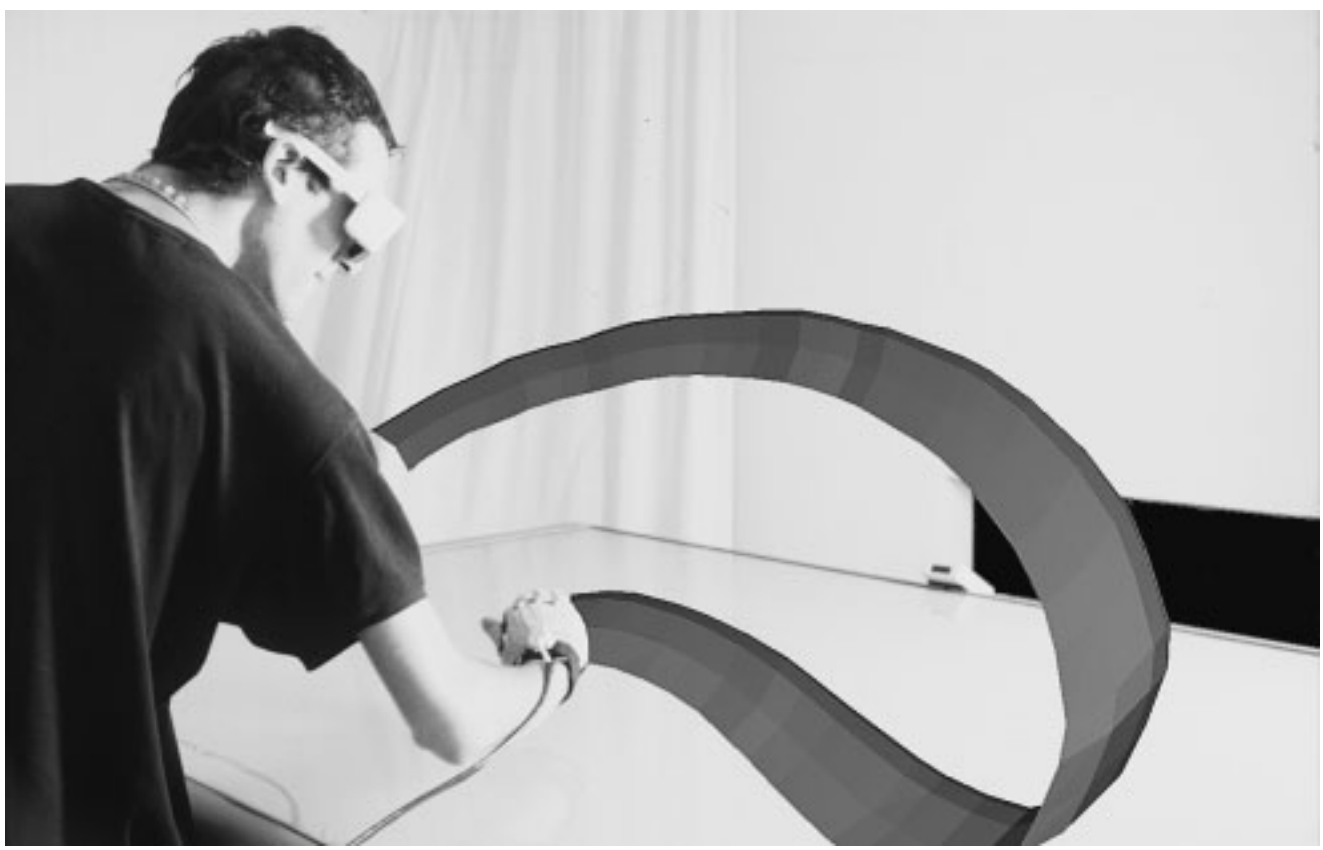
ABSTRACT

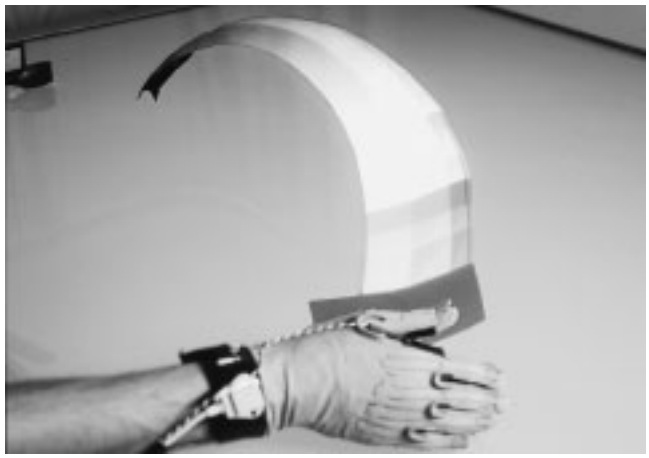
This article presents a new medium in which organic surfaces are drawn in 3D space with the hand. Special interface hardware includes a head-tracked stereoscopic display and sensors that track the body and handheld tools, allowing the artist to share the space of the artwork. Additional tools move and deform the shape. This method provides a fluid, unstructured access to three dimensions, ideal for quick, spontaneous ideation and investigation of complex structures.

The gesture has a spontaneity, a freedom, an unfiltered physicality in its instantaneous choice. There is a depth of communication in this moment—the split second of a photograph, the subtle timing of a comedian. These instants are not planned or contrived but quickly communicated through a developed intuition. Mark-based traditional media, such as drawing and painting, engage this type of moment repeatedly in a form that engages the body. I view drawing, especially sketching, as a way of physically capturing a form of thought [1]. Yet lines and the paper they occupy are two-dimensional; they do not capture the bodily space. My experience with three-dimensional physical media has been arduous: much planning for small moments of interaction and response. Computer modeling programs [2] require an indirect manipulation of form through mathematical quantities, typically with a 2D interface. I find that these laborious processes do not support the spontaneity of creation and the physical, corporeal understanding that I seek. Without this immediacy, I feel the ability to freely explore

Steven Schkolne, 1200 E. California Blvd., Pasadena, CA 91125, U.S.A. E-mail: <steven@schkolne.com>.

Fig. 1. A thin strip of surface is drawn with the hand. Special viewing hardware makes the stroke appear to float above the table, as depicted in this composite image. (Photo: Vanessa Stump)





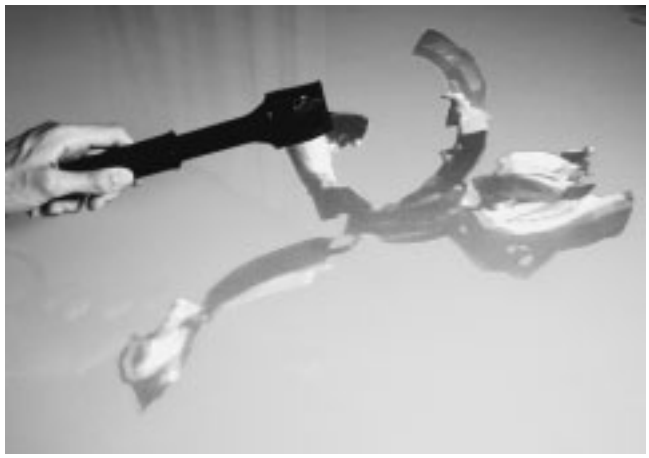


Fig. 2. Basic methods of developing surfaces: (a) The path of the hand in space is captured as a stroke. A sensor on the lower index finger detects the thumb's closing, which initiates the drawing. (b) Sensor-equipped tongs are used to rotate the figure. Two pairs of tongs used together can be used to scale an object. (c) An ergonomic 3D push-button eraser removes a small volume from an object. (d) A magnet held between the fingers attracts a surface. (Photos: Vanessa Stump)

and to thoroughly engage 3D space lacking.

The medium presented here, which I call surface drawing [3], has developed in response to these concerns. This method is an extension of line drawing to 3D space, using the hand in place of a pen. As the hand is moved through space, its path takes form and hovers in the air as a surface. This concept is realized with advanced computer-interface devices and custom software. Each hand motion is sensed by a specially equipped glove, recorded by the computer and displayed as a coherent stroke. An accumulation of these strokes forms an object, in much the same way that 2D lines combine. The action of creating with the hand is somewhat like touching an imaginary object and having it materialize. This method of creation is a recording of gesture, capturing a performative body as object. The relationship between artist and object is two-way, with the object enveloping the artist, affecting the growth of form.

This method does much to provide the relationship to 3D space that I seek. I have pursued this approach both as an artist investigating visual space and as a computer scientist (in collaboration with Peter Schröder and Michael Pruett at California Institute of Technology [Caltech]) developing a system to support this interaction. I am concerned with making a general-purpose system for the artistic community at large. To this end, I first investigated the system's ability to make representational surface drawings. More recently I have created abstract shapes that develop structural relationships unique to this medium. In both of these investigations my focus has been more on geometry than on color. This is due to my emphasis on structure and my anticipation of future work in texture and shading.

The Physical Interface

I realized this concept using the Responsive Workbench [4], a large table that acts as a display surface. To a user wearing head-tracked stereoscopic shutterglasses [5], objects appear to float above this table within the user's body space (see Fig. 1). In this environment, a number of physical tools are used to create and manipulate shapes. The user wears a motion-tracked glove [6] on the dominant hand, which senses the shape and movement of the hand. These hand motions are turned into shapes [7] by a computer, which displays them in real time (see Fig. 2). A stroke is started by closing the thumb against a sensor on the lower index finger. The color of the

stroke can be changed by turning a color wheel that rests on the tabletop.

The interface is further augmented by the following tools: A pair of kitchen tongs freely moves and rotates objects in 3D space. These motion-tracked tongs have a pressure sensor that detects when they are closed. A second pair of tongs has the same function. When the two tongs are used together they can increase the size of the object (by closing both tongs and moving them apart) or shrink it (by moving them closer to each other). This scaling changes the size of the object relative to the hand, and thus details can be added at any scale. Small features can also be created by drawing thinner strokes; this is accomplished by drawing with the hand in a pointing position [8].

Two additional tools, an eraser and a magnet, also modify shapes. The eraser is molded out of yellow silicone, designed to fit easily in the hand. When a sensor is pressed with the thumb, a small volume is removed from the 3D drawing. The magnet, somewhat like a toenail brush, fits lightly in the hand. This tool attracts a shape, pulling it slightly towards the hand. This method of overdrawing [9] does not create new geometry but rather slightly modifies it.

The pattern of these interactions is very physical. All the operations are accomplished with motion. The act of creation is a performance whose record is part of a developing interaction. The thought that goes into an object's creation is channeled through motion and perception. Guided by the action of the instant, forms emerge in reaction to space.

These elements of performance, emotion, action and the subtlety of the artist's hand are also found in abstract expressionist painting [10]. The distinctions between painting and surface drawing are noteworthy. As I have become adept at surface drawing I have come to move the object constantly as I work. The piece spins quickly, and the process is as much about seeing as doing. This interaction is different from that in action painting, where the canvas is an object of the mark. In surface drawing, marks re-enter and thus re-engage the space of the body, becoming both subject and object. In place of the static visual field of the painting, this interaction nurtures an intense form of vision that is demanding and engrossing. Through this process, an interactive contemplation of form and relationship with structure emerges that is intricate, fluid and dynamic: the goal is as much about spatial awareness, observation and reaction as expressionist catharsis.

Fig. 3. ***fwr*****, triangle mesh, 2000. This shape was created from several hand gestures: defining motions that denoted the edges of the petals, followed by motions to fill in the interior.**

Representational Shapes

My first experiences with this method focused on the creation of representational objects. Constructing such shapes requires the invention of new processes. Much as in 2D painting, drawing objects precisely in space is aided by preliminary sketching. To draw *fwr,* shown in Fig. 3 [11], I first sketched some basic petal positions. I analyzed this shape and made marks approximating more final petal positions, which served as guidelines for a refined drawing of the shape. Petals are best drawn edge first, as the edges are the defining characteristics of this form.

I find this method similar in spirit to my 2D representational process: fluid in structure, a reflection of thought through motion very much filled with the instant. I often find myself squinting my eyes to get a feel for where something should go. In stark contrast to users of current 3D modeling software, I do not have to think about *x*-*y*-*z* coordinates, interpolating curves or other linguistic handles. There is little enforced structure; whatever I imagine is directly and immediately represented. Unlike when working with physical media, I do not have to build and maintain a structure to support the flower's petals.

It is common in line drawing to render a live model during a short sitting. I duplicated this exercise with 1-minute gesture drawings. The resulting surface drawings are shown in Fig. 4. Unlike in 2D drawing, perspective was not needed. The drawing instead required sensing the model's position in my own workspace. As with the flower, this process entailed repeated rolling motions over and around the figure as I was creating it. These quick sketches have a pronounced roughness to them, a gestural quality that is inherent to their development. The chunkiness of these figures is somewhat characteristic of the graphic signature of surface drawings. One can see the figure, the crudity of manipulation, resembling work with clay, but the solidity of clay is replaced with the thinness and airiness of foil.

Abstract Shapes

I am currently investigating surface drawings that display a more abstract representation. These objects, less focused on replicating extant material forms, appear quite unlike physical sculptures or other computer-graphic shapes. Figure 5 and Color Plate B No. 1 show *fthr,* an example of this purely constructive process. These forms grow incrementally in a spatial balance. A salient characteristic of these objects is that they are hard to represent on the printed page. The three separate views of *fthr* demonstrate a rich 3D complexity. On the printed page, I find visualizing the relative rotation between each pair of images to be quite arduous [12]. Such an object is difficult to conceptualize with 2D tools.

It is this enriched understanding of structure that holds the greatest potential for this method. In this medium, spatial comprehension grows naturally as the constructive space is marked. Elements are easily placed and relations develop among the marks. This constructive process is not predetermined but proceeds in a loose and fluid manner, letting ideas grow. This physical basis for abstract thought is a perceptual tool that enables conception. The

Fig. 4. Untitled triangle meshes, 2000. These one-minute gestures were drawn from a live model. Their rapid construction and roughness demonstrate the immediacy of surface drawing.

sophistication and simplicity of the constructive process facilitate exploration with a minimum of cognitive overhead.

Other works in this series take advantage of scale, containing miniature details that are as rich as the larger form they inhabit. Their nature is difficult to represent either on the page or in physical reproduction: An interactive investigation of the form is needed. Through investigation of these shapes using scaling and rotation, the viewer is thrust into a complex spatial dialogue, the precise language of which remains undeveloped.

The objects in this series exemplify the freedom that I have been seeking in three dimensions. Their abstraction is employed in a bodily space with which the artist relates directly during construction and that interacts with the 3D viewer's body. The shapes have a materiality, a raw roughness of physicality, despite their inherent lack of physical embodiment. The stereotypically emotionally divorced, purely abstract and immaterial nature of the machine has merged with the stereotypically crude, lo-fi and Neanderthal action of the body. This merging of qualities informs a larger philosophy of mine, that as technology progresses we become more aware of our bodies, of our existence as perceptive entities, rather than fleeing into an abstract mental space that is devoid of body.

Further Applications

This method is a general way of creating 3D shapes and as such has many applications outside of purely artistic exploration. The system can be used for the conceptual design of any 3D object, including buildings, characters, cars, clothes, furniture and roller coasters. Once prototyped, shapes can be brought into standard 3D modeling applications for lighting, refinement, rendering or animation. Digital files can also be used as starting points for manufacture or directly printed as objects using 3D lithography. Surface drawings are also useful for conceptual design. For example, surface drawings can serve as conceptual sketches for a project to be completed by a traditional method such as object assembly.

I am investigating applications of surface drawing in collaboration with Designworks/USA [13], an industrial design firm interested in making surface drawings for conceptual prototypes of products, which in this case range from automobiles to cellular phones.

Designworks has experimented with the setup at Caltech, and I have built a second implementation at Designworks

Fig. 5. ***fthr*, triangle mesh, 2000. Three views of this static object reveal a complex 3D structure. This shape is poorly represented on the printed page. For example, the rotations from one shape to another are difficult to visualize. The small diagrams between the images denote the approximate rotations the shape goes through as seen by a stationary viewer. The spatial relationships inherent to this form are not easily conceptualized with 2D tools. The original 3D model is available on-line [15]. See also Color Plate B No. 1.**

to give the designers more access to the process.

I have also shown this system publicly in two recent exhibitions [14]. Viewers understand very quickly how this medium works: people begin creating shapes instantaneously. Gaining control of this medium is more difficult and requires experience. Gestural skills translate well into skill at creating shapes, although some artists begin by thinking very two-dimensionally. It takes practice to fully utilize the spatial aspects of this medium. The learning process that users go through is not one of learning how the software works, but rather of gaining an understanding of body and space.

FUTURE WORK

The medium as it stands is primarily suited to organic shapes. Perfectly flat planes, hard edges and precise symmetries are not supported by the current interface. Errors in the tracking system provide a further obstacle to high precision. Thus, for industrial concerns, the medium is not yet suitable for shapes beyond the prototype phase.

Other aspects of shape creation have yet to be developed. For example, there is no facility for controlling texture and lighting. A wider variety of spatial elements, such as volumes or time-varying components, has not been explored. There are many different additional tools that could be built to diversify and enrich the constructive process.

Developments in these many areas will enhance the physical, intuitive access to space that surface drawing provides, enriching the spatial dialogue and enlarging the resulting understanding of structure. In the future I plan to examine the vast landscape of possibility that this 3D environment provides, where any type of action can be translated into form. With improved sensors, a more sophisticated display and a wider toolset, the visual language encompassed by these techniques will be enriched, growing to become a vital component of human communication.

Acknowledgments

This work would not have been possible without the support and guidance of Peter Schröder. Michael Pruett made important contributions to the design and implementation of the surface drawing system. Special thanks to davidkremers, W. Everett Kane, Gary Fitzgerald, Alec Bernstein, Aaron Rincover and Al Barr. This work was supported in part by the National Science Foundation (DMS-9872890, ACI-9721349); other support was provided by Alias|Wavefront, the Packard Foundation, Pixar, Intel and Designworks/USA.

References and Notes

1. This viewpoint is informed by Rudolf Arnheim's work. See, for example, *Visual Thinking* (Berkeley, CA: University of California Press, 1969).

2. See, for example, Maya <http://www.aliaswavefront.com> and 3ds max <www.discreet.com>.

3. The name "surface drawing" refers to the extension of line drawing to surfaces. The action of this medium is much like line drawing, except that the marking tool produces 2D surfaces instead of 1D lines.

4. The Responsive Workbench was developed by Wolfgang Kruger and colleagues at the German National Research Center for Information Technology, GMD. See W. Kruger and B. Fröhlich, "The Responsive Workbench," *IEEE Computer Graphics and Applications* **14**, No. 3, 12–15 (May 1994).

5. These glasses provide the illusion of depth by showing different images to the left and right eyes. A transparent liquid crystal display (LCD) screen covers each eye. The left screen turns black as an image is displayed to the right eye and vice versa.

6. The Cyberglove, by Virtual Technologies Inc., Palo Alto, CA <http://www.virtex.com>.

7. The surfaces are represented as triangle meshes, collections of colored triangles in 3D space with connectivity information. More technical details can be found in Steven Schkolne, "Surface Drawing: The Perceptual Construction of Aesthetic Form" (M.S. thesis, Computer Science, Caltech, 1999), <http://www.cs.caltech.edu/~ss/sdraw/pubs>.

8. Computer users often ask for a feature such as the ability to precisely adjust the stroke width. My interface philosophy here is one of minimalism, however. It is not necessary to create a stroke-width knob if a similar effect can be achieved with the current tools (in this case, scaling).

9. This method was inspired by the work of Cohen on overdrawing curves. See J.M. Cohen et al., "An Interface for Sketching 3D Curves," *1999 ACM Symposium on Interactive 3D Graphics* (1997) pp. 107–114.

10. Irving Sandler, *The Triumph of American Painting: A History of Abstract Expressionism* (New York: Praeger Publishers, 1970).

11. More images, along with further description of this project, can be found at <http://www.cs.caltech.edu/~ss/sdraw/>.

12. A 3D version of *fthr* is available on-line at <http://www.cs.caltech.edu/~ss/sdraw/gallery/fthr.html>.

13. <http://www.designworksusa.com>.

14. Surface Drawing has been exhibited twice, first at SIGGRAPH 1999's Emerging Technologies forum, Los Angeles, CA, August 1999. The second exhibit was at the 3rd Petrobras Mostra de Realidade Virtual, Rio De Janeiro, June 2000. Both exhibits involved showing audience members how to use surface drawing.

15. <http://www.designworksusa.com>.

Manuscript received 17 July 2000.

Steven Schkolne is a Ph.D. candidate at Caltech. In addition to the work described in this article, he also makes projections that hang on walls. Born in Cape Town in 1976, Schkolne currently lives and works in Los Angeles.