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Department of Computer Science
and Engineering
University of Minnesota
4-192 EECS Building
200 Union Street SE
Minneapolis, MN 55455-0159 USA

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Designing with Your Hands: Using 3D Computer Interfaces and Gesture to Model Organic Subjects

Daniel F. Keefe

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Abstract

This paper reviews recent advances in human-computer interfaces for 3D free-form modeling using hand-based input and presents new results attained with these methods applied to modeling organic subjects. Recent interactive algorithms, including those utilizing force-feedback devices, have made more controllable hand-based 3D computer input possible. With this advance, 3D modeling tools may now better take advantage of the gestural, immediate input available from our hands. 3D models created with this type of input tend to exhibit a loose, immediate aesthetic that is unusual in computer aided design and photo-realistic computer graphics. This paper presents an analysis of the visual form seen in several works produced with 3D modeling tools in this style. A series of organic modeling subjects, primarily artistic anatomical illustrations of the human form, are explored. The modeling styles utilized are found to be quite similar to those seen in traditional gesture drawings. In particular, a tight physical/kinesthetic connection with the form-maker is evident in the results. This gestural style of computer input appears well suited for modeling organic subjects and for performing spatial design tasks, particularly in early, less precision-oriented stages of design.

1. Introduction

3D modeling using computers has a relatively short, but rich history in design, art, and illustration. Computer tools have been readily adopted for modeling tasks that require precision. For example, in industrial design, if we know the wheelbase on a bicycle needs to be a certain dimension, then computers are very good at helping us enforce this constraint within a modeling system so that we may design the frame and other parts with exact measurements to fit the bicycle. Due to the exact coordinate system representations within the computer, 3D models created using this paradigm are often easily exported to fabrication systems. Clearly, this use of computers is extremely valuable, but what role might computers play in less-precise modeling tasks? How do we best match the strengths of computers with the less-precise requirements of other stages of a design process? How, for example, does sketching with traditional media, a less-precise task, but clearly invaluable for visual thinking and design, intersect with the world of 3D computer-based design strategies?

We have a keen interest in investigating questions such as these that work toward a better understanding of the most appropriate roles for computers in real-world design, illustration, and art practice. In this paper, we present a review of recent human-computer interface advances that impact this area. The tight connection in these interfaces between hu-

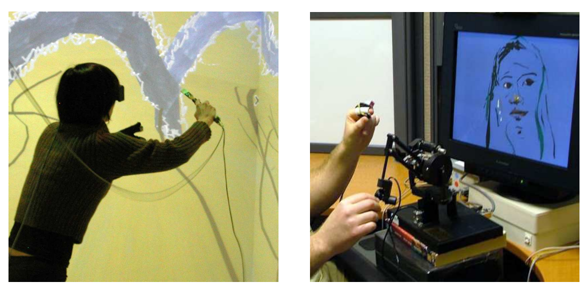

Figure 1: *3D modeling tools using input from the hands. A large scale virtual reality environment using body-scale interaction is shown on the left. A desktop virtual reality system equipped with a force-feedback device is shown on the right.*

man hand movements and generated computer form seems to make this style of input particularly useful for modeling organic and biological subjects. Building upon these interfaces, we present an analysis of several hand-crafted 3D models that exhibit an interesting loose, organic quality. These models seem to capture something similar to a sketch created with more traditional media, in the sense that we see evidence in the final work that a human hand was involved in creation of the form. Artists report that the tools employed to create these models are immediate, gestural, and "feel" physical in the way that drawing or painting does. We believe there is a promising future for this style of modeling within many design, illustration, and art practices.

The key technology making this style of 3D modeling possible is the use of 3D hand-based computer input. Recent advances in this area are reviewed in the next section. Following this, a critique of 3D models created by several artists within our working group is presented. Several themes for working with this style of modeling and implications for future modeling tools and processes are discussed.

2. Recent Advances in 3D Input for Modeling

3D computer input from the hands is typically captured via a 3D tracker attached to a prop held in the hand or a glove. As the hand moves through space, its trajectory is recorded by the computer. In modeling tools based on this style of input, the user is typically immersed in a stereoscopic virtual reality display, and a virtual geometry is produced in the wake of the hand as it moves through space. Thus, the 3D form displayed by the computer is defined directly via movements of the hand. Several modeling systems based on this style of input have been presented [Dee96, KFM*01, SPS01]. These vary in the display and input form-factors used. For example, in the CavePainting system [KFM*01] pictured in Figure 1 (left), artists work in a large scale virtual reality environment. Large, sweeping motions of the arm and hand are often used. Smaller, desktop-scale systems have also been explored.

A traditional limitation of this style of input is that it is a bit *too* loose and gestural. Without the aid of a surface against which to steady the hand, it is very difficult to make drawing-style motions with control. It tends to be easy to scribble but difficult to model representational subjects. In recent work, force feedback [KZL07], dynamic constraint-based input [KZL08], and filtering techniques [FMRU03] have been employed with success to increase control of this style of input. The desktop scale "Drawing on Air" tool, pictured in Figure 1 (right), uses force-feedback, input filtering, and a combination of one and two-handed input strategies to provide controlled, stylized 3D input. The result is an interface that retains a hand-crafted sensation, but increases artists' control to the point that they may address challenging visual subjects, including 3D anatomical illustrations.

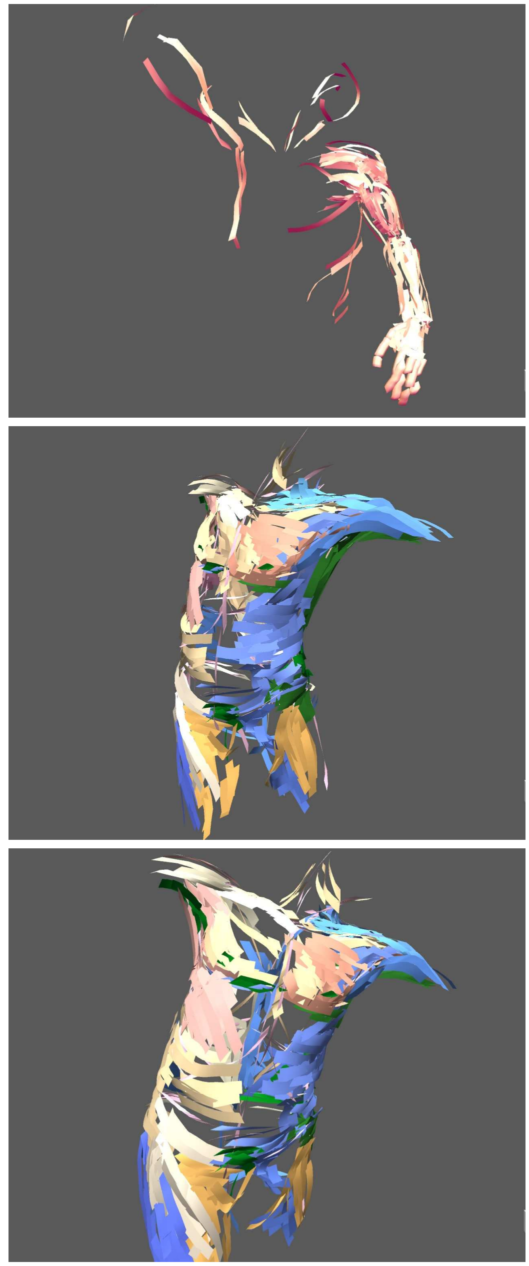

Figure 2: *"3D Gesture models": These models, hand drawn using 3D input, exhibit an immediate, gestural quality, similar to traditional gesture drawing. The bottom two images are rotated views of the same 3D model. Artist credit: Mr. A.*

3. Moving From 2D Gesture Drawing to "3D Gesture Modeling"

Figure 2 shows results from anatomical "3D gesture models" created with a large-scale modeling tool called CavePainting [KFM*01]. (Note that all of the images in this paper are

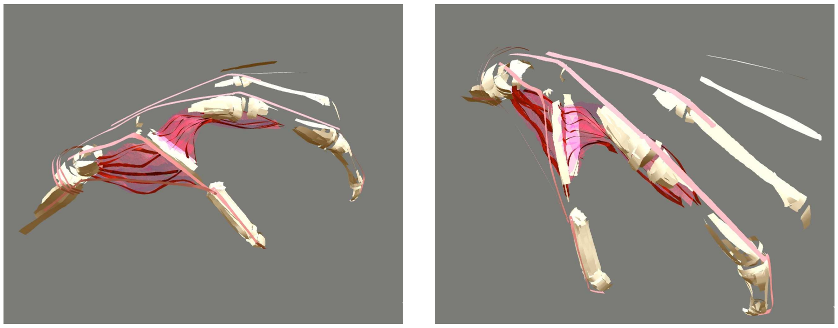

Figure 3: *The artist makes economic use of "line" in this model, suggesting rather than fully specifying many of the surfaces. Artist credit: Mr A.*

Figure 4: *In contrast to the model in Figure 3, a much more sculptural approach is adopted to model a lionfish (left, middle) and a falcon (right). Artist credit: Ms. B.*

flattened 2D views of 3D models that were created in virtual reality environments.) Even when printed on paper, we see some evidence of the qualities that have led us to think of these as "gesture models" – 3D extensions of gesture drawings. For example, in both models, notice the quick indication of the neck. A few simple 3D marks have been swept out by the artist's hand to provide an indication of the sternocleidomastoid muscles running up from the clavicle to their attachment points behind the ear. The quick motion of the hand in the air used to describe this form is a 3D mirror of the physical action an artist would take when drawing with charcoal on paper.

4. The Function of "Lines" in 3D Space

An exciting question that is explored by many of the models displayed here is: In gesture modeling, what mark should the hand produce as it moves through the air? In other words, what is the 3D analog to a pencil line? Most of the models here interpret a 3D line as a ribbon, but the software used could easily map user input to all types of forms, from simple tubes to trails of animated raindrops. The right mapping to use is likely to depend upon the application. Our experimentation suggests that ribbons are a good choice for a variety of applications. Ribbon forms have also been used with success by others. The digital artist, Csuri, has also explored ribbons as a 3D modeling primitive [Csu08]. In physical media, Gillespie, makes use of similar painted ribbons in her sculpture, of course with the constraint imposed by the non-virtual world that the resulting form must stand up to gravity [MBB*98]. Ribbons are simple enough that the complexity of the form produced results almost completely from the user's manipulations, thus, they seem appropriate for describing a wide variety of modeling subjects.

4.1. Suggestion and Economy of Line

Figure 3 shows a model of a hand, created with the Drawing on Air tool [KZL07], in which much of the form is suggested rather than fully specified. Again, this is a common artistic technique, but something seen only rarely in computer-based tools that tend to require exact rather than suggestive definitions of form. Single ribbon-lines are used to suggest the tendons of several of the fingers in this model. In addition, in the bones of the index finger, we see several cases where the ends of the bone are defined rather solidly, but the less important connecting areas are simplified to the point of being left out of the model.

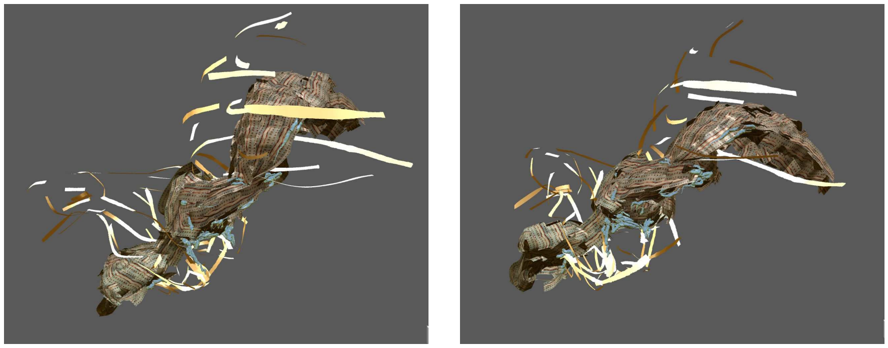

Figure 5: *This model of hands wringing out a towel is difficult to interpret without the aid of stereo viewing. The hands are described with minimal use of 3D form, making them nearly transparent. When seen in stereo, the human visual system reads the spatial cues provided by the ribbon surface patches, allowing us to understand the forms suggested here. Artist credit: Mr. A.*

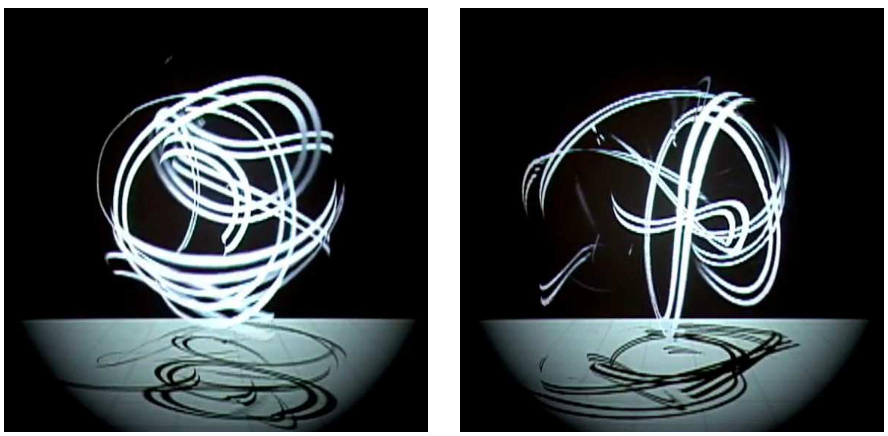

Figure 6: *This model explores the use of one-sided ribbon forms. Since these are impossible to realize in physical space, their visual interpretation is quite interesting, especially when seen in motion in an animated virtual reality display. Artist credit: Mr. C.*

4.2. Contrast with More Sculptural Approaches

The models shown in Figure 4 were created with the CavePainting tool [KFM*01]. Compared to the results in Figure 3, similar hand-swept movements were used to create the form, but Figure 4 demonstrates a different, more deliberate style. The lionfish and falcon models are quite sculptural. Individual marks made by the hand run into each other producing the effect of a solid surface. Many of the marks are also textured. For example, a texture produces the repeating striped pattern seen on the spikes of the lionfish. Seen together, the different approaches highlight the range of forms possible to achieve with hand-based 3D input. Like pencil lines in drawing, these relatively simple primitives leave room for artists to combine them in many new ways.

5. Effects of Head-Tracked Stereo Viewing

Figure 5 is quite difficult to interpret when not seen in a head-tracked stereo environment. This work illustrates an interesting aspect of perception in virtual reality environments. Depicted in this model are two hands wringing out a towel. The artist has chosen to merely suggest the forms of the hands with the simple yellow lines that are seen in these pictures. Thus, most of the surface of the hands is transparent. In contrast, the towel is depicted using a much more sculptural approach.

While difficult to interpret when printed on a page, when this model is seen in a head-tracked stereo environment, our brain is quite capable of interpreting the form of the hands. The tiny bits of surface indicated by the ribbons give us strong cues for the spatial position and orientation of the hand surfaces. The result is a style of form that could not be realized in the physical world, is very difficult to interpret in a 2D projection, but nevertheless is intriguing and well understood when viewed in virtual reality.

The model in Figure 6 builds on this same principle. This form was created with one-sided ribbons. That is, the computer graphics primitive used to render the form is a triangle strip with only the front-facing triangles rendered. This makes the ribbon look opaque when seen from the front, and transparent when seen from the back. The artist has created an intertwined bird's nest form using these ribbons. The piece is intended to be viewed as an animation, with the form constantly rotating.

The effect is engaging, since there is a constant visual tension in this work as we attempt to understand the shape of this form. It seems to exhibit a worldly organic quality, but at the same time, it is obvious that this object does not exist in the physical world – it can only exist in virtual reality. As the piece rotates new bits of ribbons become visible and others disappear, inviting us to reinterpret our notion of the 3D shape.

6. Implications for Future Tools

The series of 3D modeling results presented here suggest several directions for future investigation. The first is further exploring the notion of "3D line." What virtual form should the hand create as it moves through space? How do we most effectively map our physical motor controls to non-physical forms? In the Drawing on Air system [KZL07], force feedback capabilities were used to create a sensation similar to the friction we feel as we move a pencil on paper. By pushing against the force generated by a robotic armature, artists dynamically adjusted the line weight of the mark as they drew. The inclusion of this effect increases the richness of hand-based computer input. Ultimately, if we expect our hand-crafted virtual creations to be as rich as those we find in the physical world, input strategies that approach the richness we find in the physical world seem to be necessary. Future tools will benefit from additional exploration of “rich” input techniques.

Perceptual differences between stereoscopic and non-stereoscopic viewing have been documented previously [WF96]. The results shown in Figures 5 and 6 revisit this discussion with a slightly different approach. These examples highlight the potential of designing specifically for the perceptual differences we find in virtual reality. With continued exploration, we hope to better understand how to best utilize characteristics of human perception in stereoscopic virtual environments for artistic effect. For example, artists and illustrators may make minimal use of “line” in a 3D illustration to clarify the depiction and introduce interest within a work.

7. Conclusions

In this paper, we bring together several 3D free-form modeling results to demonstrate the characteristic qualities, limitations, and future potential of form created via hand-based 3D input. The results may be described as immediate and gestural. They often exhibit clear evidence that a human hand was involved in the form making process, leading us to characterize this style of work as "3D gesture modeling". Gesture modeling has potential to play an important role in future design, art, and illustration processes. Key themes as this work progresses will include: creating rich mappings from hand movements to virtual forms, defining the role and function of “lines” in 3D hand-crafted models, exploring the various styles of form possible with 3D input, and understanding human perception in stereoscopic virtual environments.

The act of sketching is, of course, integral to many design processes. As these processes become increasingly defined by computer tools, we hope to develop useful tools that bridge the gap between traditional physical-media design and current precise computer-based design. We believe rich, spatial, hand-based input will provide a valuable interaction space for these future design tools.

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