Creative 3D Form-Making in Visual Art and Visual Design for Science

Daniel F. Keefe
Department of Computer Science and Engineering
University of Minnesota
200 Union Street SE
Minneapolis, MN 55455
keefe@cs.umn.edu

ABSTRACT

This paper presents the view that computer tools to support creative 3D modeling practice in art and visual design may benefit significantly from utilizing spatial 3D input captured from our hands. Traditionally, real-world applications have made only limited use of this style of input because it can be difficult to control. Recent interface advances have begun to overcome this limitation, allowing artists and visual designers to explore free-form 3D input from the hands as a creative tool for modeling challenging organic subjects, exploring new styles of representation of form, and prototyping complex visual ideas in collaboration with scientists. Several of these developments are reviewed within this paper. We believe this style of input shows great promise for creativity support tools, in part because the immediacy and physicality of it relates so well to traditional techniques, such as sketching, that are critical in almost all visual design processes. We raise the question of how to best combine the rich, free-form input that is possible to capture from our hands with algorithms that interpret the input relative to modeling constraints or scientific data. We hope to engage both artists and computer researchers in a discussion of how rich, descriptive human movements may be input to the computer and combined with data-driven algorithms to support new creative processes.

Author Keywords

Free-form modeling, 3D user interfaces, artistic interfaces.

ACM Classification Keywords

H.5.2 Information Interfaces and Presentation: User Interfaces—*Input devices and strategies*

INTRODUCTION

Computer-based 3D modeling tools, such as computer-aided design (CAD) systems and character modeling and animation systems [1], have a rich history of use within creative disciplines such as architecture, design, and movie making. While these tools undoubtably allow for creative expression, a shortcoming of their use in current design practice is the disconnect that arises between current computer tools and

Computational Creativity Support Workshop
Using Algorithms and Machine Learning to Help People Be More Creative
CHI 2009, April 3 - 9, 2009, Boston, MA, USA.

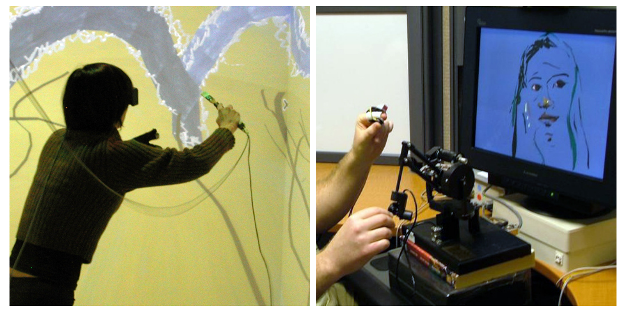

Figure 1. 3D modeling tools using input from the hands. A large scale virtual reality environment using body-scale interaction is shown on the left. A desktop virtual reality system equipped with a force-feedback device is shown on the right.

the more loose, exploratory qualities of traditional physical design tools, such as sketching. If new styles of 3D modeling tools can close this gap, then we may expect improvements to many design processes, both in the arts and in industrial design. We may also expect new creative processes to be possible, for example, with intuitive sketch-inspired interfaces for 3D construction, it may be possible to shift the design task of early concept generation from one currently performed predominately with 2D physical media to one performed with 3D virtual media, allowing designers and artists to focus more completely on 3D proportion and structure early in their processes.

In this paper, we review recent and propose future human-computer interface advances impacting this area. In particular, we focus on strategies based upon free-form input from the hands in space – "sketching in the air". Figure 1 documents two different approaches in this style. Large-scale, virtual reality systems in which an artist may stand up and move about within her creation are possible (Figure 1 left), as are smaller-scale desktop systems (Figure 1 right).

In the next section, we describe recent advances for working with these free-form input technologies. Then, we describe in more detail some promising applications of this style of input. Finally, we discuss several open research questions that we believe will be of interest to both the art/design community and the computer science community.

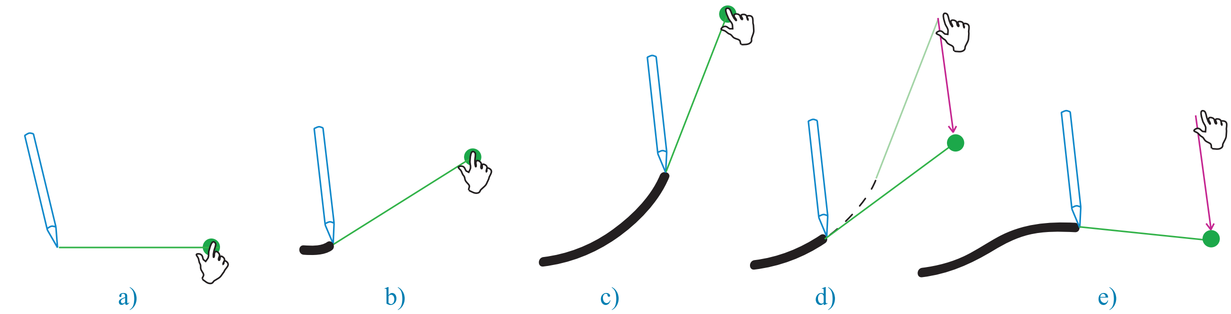

Figure 2. The progression of a Drawing on Air two-handed interaction for input of a 3D curve (left handed user). The drawing direction is determined by the position of the right hand and the endpoint of the curve being drawn. To draw a curved path, both hands must move together (position a through c). The user sets the drawing direction with the right hand, then advances incrementally along this direction with the left hand. If a mistake is made, the user may back up to redraw a portion of the curve (d). In this case, a virtual offset (shown as a magenta vector) is automatically applied to the hand position so that a tangent preserving transition is made when forward drawing resumes (e). This two-handed approach to computer input provides the user with a guideline and a filtering mechanism, making direct input of smooth, controlled 3D trajectories possible.

RECENT ADVANCES IN VIRTUAL 3D FORM-MAKING

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 [2, 6, 9]. These vary in the display and input form-factors used. For example, in the CavePainting system [6] (Figure 1 left), artists work in a large scale virtual reality environment. Large, sweeping motions of the arm and hand are often used.

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 [7], dynamic constraint-based input [8], and filtering techniques [3] have been employed with success to increase control of this style of input. The desktop scale "Drawing on Air" tool (Figure 1 right) uses force-feedback, input filtering, and a combination of one and two-handed input strategies to provide controlled, stylized 3D input. These techniques work together to provide an interface that retains a hand-crafted sensation, but increases artists' control to the point that they may address challenging visual subjects, including the 3D anatomical illustrations and scientific models presented in the remainder of this paper. The two-handed input strategy employed in Drawing on Air is described in more detail in Figure 2.

APPLICATION 1: ARTISTIC ANATOMY

An exciting artistic application for this technology is 3D modeling of anatomical subjects. Two results in this style are shown in Figures 3 and 4. Both models exhibit a hand-crafted, organic quality that is rare in computer graphics. Indeed, the aesthetic is quite similar to traditional gesture drawing using paper and pencil, but here the results exist as 3D virtual models. The tight physical connection between the form maker's movements and the resulting form is what makes this aesthetic possible. It is rare for a 3D computer interface to exhibit both this tight physical connection *and* the level of control needed to address complex representational subjects, such as these. Consider input of the 3D curves that define the tendons, running over the knuckles in the hand shown in Figure 4. These curves are smooth and exact, and they have been precisely placed in 3D space relative to other bits of the model. This is the type of feature that is traditionally very difficult to describe to the computer using a 3D interface. We are now beginning to overcome some of these traditional limitations.

Artists have been creative in their use of this new technology. One topic that has been the focus of many discussions with our collaborators is exploring new visual styles for 3D virtual forms. Our software allows artists to map colors, textures, and simple geometries (ribbons, cylinders, etc.) onto the 3D curves they specify with these interfaces. How are these primitives best combined to suggest subjects in art or in medical illustration? We do not yet know the full answer, however, one key seems to be that the simple 3D ribbon forms seen in the figures in this paper function in much the same way that a pencil line does. In other words, these ribbons may be used as a suggestion of a larger 3D form. For example, notice how several of the fingers of the hand in Figure 4 are merely suggested, rather than fully specified. This is a departure from typical use of 3D modeling software, where 3D triangle meshes explicitly define an entire watertight surface.

APPLICATION 2: PROTOTYPING SCIENTIFIC VISUALIZATIONS

A second application for this technology is design. Our group has explored this primarily within the context of designing effective scientific visualizations for use in virtual reality, however, many of the lessons learned from this work are likely to translate to industrial design and other contexts. Figure 5 shows several 3D models that artists and computer scientists have hand-drawn using the 3D computer interfaces described previously. These examples come from a interdis-

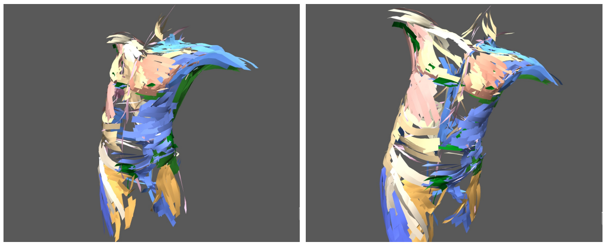

Figure 3. This 3D model of a human torso was hand drawn using 3D input. It exhibits an immediate, gestural quality, similar to traditional sketching.

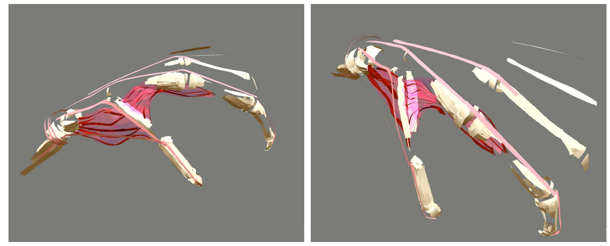

Figure 4. In this 3D model, created in the style of medical illustration, the artist makes economic use of “line”, suggesting rather than fully specifying many of the surfaces.

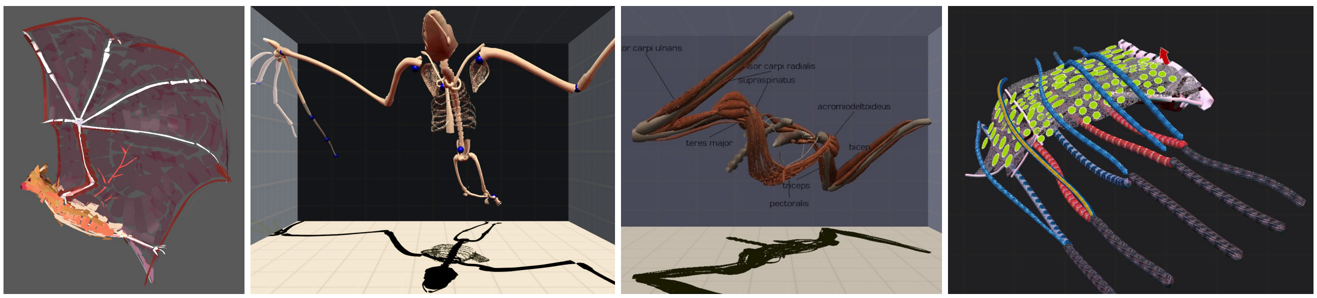

Figure 5. These hand-drawn 3D models illustrate scientific concepts: the anatomy of a bat posed in flight and the airflow, pressure, and generation of lift for a bat’s wing.

ciplinary collaboration with evolutionary biologists studying the evolution of flight in bats. The models shown in Figure 5 are 3D anatomical illustrations intended to be used by the biologists for teaching and better understanding the bat’s anatomy with reference to specific flight poses. Also shown (Figure 5 right) is a visual design for representing six variables describing air flow around a bat’s wing during flight. The data motivating this design are collected from wind tunnel experiments, but interpreting this data is a challenge. One of our goals is to think of this as a visual design problem. How do we design the most effective visual possible for simultaneously representing all this data? These examples explore the use of hand-crafted 3D models as a way of performing this visual design. Using these tools, we have outlined a design process that includes first sketching designs on paper, then sketching 3D designs in virtual reality, then critiquing these designs directly in virtual reality together with scientists [5].

DISCUSSION: RICH INPUT PLUS SMART COMPUTATION

To advance the tools described here and others based upon free-form input from the hands, we believe an exciting next step is to consider the role of computational algorithms in guiding and interpreting the rich input we can obtain from our hands. Some examples motivated by the applications described in this paper follow.

Computing 3D Input Constraints as You Work

We envision future design tools where each mark that an artist makes is interpreted by an underlying computational model that is built up in detail and power as the artist works. Properties of the 3D sketch that may be analyzed would include proportion, symmetry, alignment of marks, and line style. The algorithms and data structures required to extract specific information on these topics from an artist’s 3D creation are currently unknown, but recent work in characterizing the style of 2D line drawings is certainly related [4].

The benefit of having such a model would be that it could help interpret the user’s input, simplifying the requirements of inputs that are difficult for the user to make. Aligning a curve with previous ones by matching curvature or positioning would be a semi-automatic operation. Certainly the artist would still want to drive the process, but an underlying algorithm would be responsible for determining how much of the artist’s input to interpret literally and how much to interpret as a query into the existing data model, perhaps of the form: ‘look for marks near the current one and adjust the current raw input to reflect a curvature similar to already existing marks.’ Similarly, the style and geometric properties of marks may be adjusted automatically to provide accurate symmetry or proportion in a model if such a thing is desired for the subject at hand.

Illustrating Scientific Data Sets

Similar computational aids may play an important role in generating custom 3D illustrations for science in the style of those seen in Figure 5. Consider developing a 3D illustration of airflow around a bat’s wing. An artist will want to both stay truthful to the underlying data and also be selective about the style and content included in the illustration so as to emphasize the important points of the illustration.

To create these scientific illustrations, we envision a design system that exists on top of a scientific visualization engine. As an artist makes a mark to convey air flow moving across the bat's wing, the style of this mark is adopted, but its exact form is reinterpreted to match the real underlying scientific data. Everything that the artist draws is adjusted if needed to reflect underlying data values. In this way, the artist specifies a mapping from data to visual in the sense of the forms, colors, textures, etc. used to describe data, but the actual display is data generated. Current visualization software often tries to mimic the look of traditional illustration. This is certainly useful in many instances, but what we currently lack is a process for hybrid illustration, combining human input from real illustrators with data-driven models provided by the computer. Tools supporting this approach will allow us to better incorporate the creativity of artists and illustrators in the results of scientifically-oriented software systems.

CONCLUSION

Utilizing free-form 3D input from our hands within computer 3D modeling tools can open the door to new application areas and new creative processes. With the advent of several interaction strategies allowing for more controllable 3D input using our hands, we have been able to begin to explore some of these possibilities. An exciting future direction for this work is combining the rich, descriptive input we get from these new interfaces with computation. We see this approach as providing real benefits to creative processes in a variety of disciplines, from art to visual design for science, but the details of what may be possible and how to go about achieving it remain undefined. We look forward to future discussions on these topics and on the general theme of combining rich human input with computation to facilitate creative work.

Acknowledgment

The author wishes to acknowledge the contributions of colleagues David H. Laidlaw, members of the Brown University Visualization Research Lab, and members of the Illustration Department at the Rhode Island School of Design to the work discussed within this paper.

REFERENCES

1. Autodesk Maya software. `http://www.autodesk.com`.
2. M. F. Deering. The holosketch vr sketching system. *Communications of the ACM*, 39(5):54–61, 1996.
3. M. Fiorentino, G. Monno, P. A. Renzulli, and A. E. Uva. 3D sketch stroke segmentation and fitting in virtual reality. In *Proceedings of GRAPHICON*, pages 188–191, 2003.
4. A. Hertzmann, N. Oliver, B. Curless, and S. M. Seitz. Curve analogies. In *Proceedings of the 13th Eurographics workshop on Rendering*, pages 233–246, 2002.
5. D. F. Keefe, D. Acevedo, J. Miles, F. Drury, S. M. Swartz, and D. H. Laidlaw. Scientific sketching for collaborative VR visualization design. *IEEE Transactions on Visualization and Computer Graphics*, 14(4):835–847, 2008.
6. D. F. Keefe, D. A. Feliz, T. Moscovich, D. H. Laidlaw, and J. J. LaViola Jr. CavePainting: A fully immersive 3D artistic medium and interactive experience. In *Proceedings of I3D 2001*, pages 85–93, 2001.
7. D. F. Keefe, R. C. Zeleznik, and D. H. Laidlaw. Drawing on air: Input techniques for controlled 3D line illustration. *IEEE Transactions on Visualization and Computer Graphics*, 13(5):1067–1081, 2007.
8. D. F. Keefe, R. C. Zeleznik, and D. H. Laidlaw. Tech-note: Dynamic dragging for input of 3D trajectories. In *Proceedings of IEEE Symposium on 3D User Interfaces 2008*, pages 51–54, 2008.
9. S. Schkolne, M. Pruett, and P. Schröder. Surface drawing: creating organic 3D shapes with the hand and tangible tools. In *Proceedings of CHI '01*, pages 261–268, 2001.