A Haptic Interface for Creating Smooth 3D Curves with Varying Line Weight

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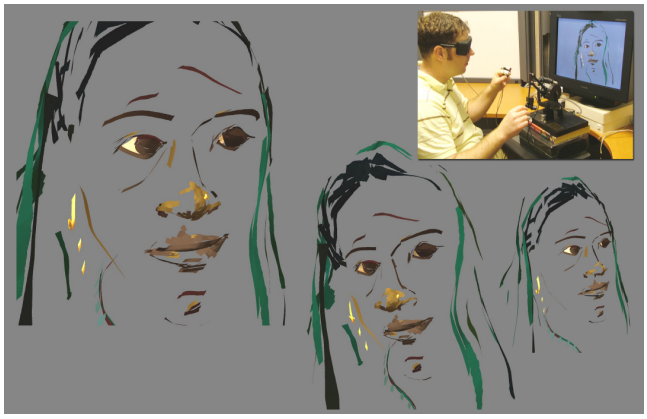

Figure 1: 3D model of a young Swahili bride wearing a green veil. The model was created with our interface and is seen here from three different viewpoints. Inset: the VR working environment.

We present a two-handed haptic interface for free-form 3D modeling in virtual reality that provides the artist with the ability to input controlled, smooth, 3D curves and to naturally vary line weight while drawing a 3D mark. As free-form modeling tools are used to tackle more and more complicated subjects, such as scientific illustrations [Keefe et al. 2005], artists are finding that they need more control over their modeling tools. This interface is an attempt to provide artists with more control in specifying both 3D form and style. The modeling medium we use for this project is something like virtual wire sculpture: 3D models made of thin ribbon-like curves. These curves are typically viewed with a stereo virtual reality display and they exist in a three-dimensional space, so they can be viewed from any direction (three views of an example model are shown in Figure 1).

The goals for our interface are: 1. to help artists create complex 3D curves that are smooth, i.e. have less jitter and bumpyness than what we often see when inputting a curve by drawing a path directly in the air with a 3D tracker, and 2. to provide artists with a natural way to vary the line weight of a mark as they are creating it. When drawing with pencil artists continually vary the pressure of the pencil against the paper to control the weight of the mark. They use this technique to help convey lighting and form, and also to establish a style and feeling in the drawing. When we move a tracker through the air to input a 3D curve, as is commonly done in free-form modeling tools like CavePainting [Keefe et al. 2001], there is no paper to push against. The richness of this physical interaction is absent, and with it the ability to intuitively control line weight. Our interface attempts to restore some of this physical interaction for artists working with free-form modeling with the hope that providing more artistic control over the medium will allow artists to explore much more complicated and valuable subjects.

Our system uses a fishtank (desktop-based) virtual reality setup with two Polhemus magnetic trackers, one tracking the artist's head and one tracking his non-dominant hand. The stylus of a SensAble Phantom force feedback device is held in the dominant hand.

The two-handed drawing approach that we use is inspired by tape drawing and recent work on digital implementations of the technique [Grossman et al. 2002]. Traditional (non-digital) tape drawing has been used for years by car designers to make life size drawings of cars. Both hands and a roll of thin black tape are used to draw. One hand pushes the tape against the wall to advance the curve being drawn, while the other pulls the tape taught in a straight line, essentially specifying the tangent for the next part of the curve to be drawn. Both hands must move together to draw a curve, which takes some practice to control, but the great advantage of this drawing technique is that it produces very, very smooth curves.

Our interface implements a 3D, digital version of tape drawing. The magnetic tracker on the non-dominant hand is used to specify the direction of drawing. The dominant hand holds the stylus of the Phantom device. When the Phantom's stylus button is pressed and held, drawing begins. From that point on, the drawing direction is constrained (through force feedback) to move toward the non-dominant hand. The force to keep the Phantom drawing along the correct line is modeled as a damped spring force that inhibits movement in all directions except toward the non-dominant hand. In our implementation of 3D tape drawing, the non-dominant hand can move anywhere, so lines can be drawn in any direction in 3-space.

As the artist draws, he can push against the force applied by the Phantom device to control the line weight of the mark. Unlike flat paper that we use in the "real" world, our virtual paper effect is 3D. One way to think of it is as if the Phantom's stylus is stuck inside a very thin tube of paper, where the tube is oriented such that its axis is aligned with the current drawing direction specified by the position of the non-dominant hand. Note that this direction is constantly changing as the artist moves his non-dominant hand. Forces are applied to the Phantom to keep the stylus stuck inside this thin tube, but allow it to slide easily down the length of the tube. When the artist pushes against the side walls of the tube the line weight of the mark is adjusted in proportion to the amount of force he applies.

Our system is in its initial stages and has seen only limited artistic use so far, however, the small working space of our Phantom device already seems to be one of the main limitations of our implementation. Our version of tape drawing is on a scale that is at least ten times smaller than the scale used in car design. Interestingly, even at this small scale, the technique produces very smooth curves, but two handed movements do feel constrained in the small working space. We are, however, very encouraged by the improved level of control that we can achieve with this interface. The smoothness of the curves is noticeable when the models are viewed in stereo, especially when compared to other models produced with direct input from a tracker held in one hand.

GROSSMAN, T., BALAKRISHNAN, R., KURTENBACH, G., FITZMAURICE, G., KHAN, A., AND BUXTON, B. 2002. Creating principal 3D curves with digital tape drawing. In *Proceedings of Computer-Human Interaction Conference*, 121–128.

KEEFE, D., ACEVEDO, D., MOSCOVICH, T., LAIDLAW, D. H., AND LAVIOLA, J. 2001. CavePainting: A fully immersive 3D artistic medium and interactive experience. In *Proceedings of ACM Symposium on Interactive 3D Graphics 2001*, 85–93.

KEEFE, D., KARELITZ, D., VOTE, E., AND LAIDLAW, D. H. 2005. Artistic collaboration in designing VR visualizations. *IEEE Computer Graphics and Applications* (March/April).