Immersive VR Touch Workbenches: Applications in Engineering and Art

Dane Coffey
University of Minnesota
200 Union St SE
Minneapolis, MN 55455 USA
coffey@cs.umn.edu

Bret Jackson
University of Minnesota
200 Union St SE
Minneapolis, MN 55455 USA
bjackson@cs.umn.edu

Chi-Lun Lin
University of Minnesota
111 Church St SE
Minneapolis, MN 55455 USA
linxx691@me.umn.edu

Arthur G. Erdman
University of Minnesota
111 Church St SE
Minneapolis, MN 55455 USA
agerdman@me.umn.edu

Daniel F. Keefe
University of Minnesota
200 Union St SE
Minneapolis, MN 55455 USA
keefe@cs.umn.edu

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Abstract
We present a discussion of the potential and anticipated impact of immersive VR touch workbenches for creative 3D work in engineering and art practice. The discussion highlights three recent interaction techniques developed for these applications. Based on this experience, we formulate a set of guidelines and domain specific challenges to guide future practitioners.

Author Keywords
Touch, stereoscopy, interaction, engineering, art

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Interaction Styles.

Introduction
The advent and recent proliferation of immersive VR and touch interaction technologies has opened up exciting new modes of interacting with computers. We believe combining these technologies can have a great impact on many applications. Stereoscopic VR environments provide a level of immersion that traditional computing experiences lack, but precisely controlling input via traditional 6-DOF wands is difficult, and using these environments can be physically tiring. Touch-based interfaces may help to address these challenges. Touch input can provide a high bandwidth

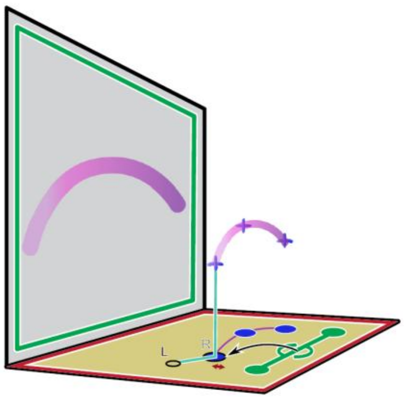

Figure 1. A sequence of control points is manipulated on the touch surface using the Balloon technique to define a 3D curve.

input channel, natural support for collaboration [3], and a direct style of input that closely mimics how we interact with physical objects [5]. Unfortunately, using touch interfaces for more than simple tasks is often challenging; in particular, new methods are needed for using touch to interface with 3D content.

In this paper we present a set of three example touch interactions developed for next generation immersive workbenches, which provide head-tracked stereoscopic viewing (characteristic of immersive VR environments) and also rich, multi-touch input (characteristic of emerging forms of surface computing). The examples are applied to tasks in both engineering and art. Our aim in presenting these examples together is, in part, to argue that immersive VR touch workbenches can be valuable platforms for exciting new applications that require immediacy, expressiveness, and control – a combination of qualities that is traditionally elusive in both VR and surface computing.

Figure 2. A user specified generalized cylinder that follows the centerline curve of the ascending aorta.

Example Interaction Techniques

The following three interaction techniques highlight the new potential we see for immersive VR workbenches, both in terms of enabling new styles of interacting with computers and also opening up new applications in engineering and art. The examples come from two interdisciplinary applications studied in our research group. The first application aids engineers in the fundamental tasks of querying and interrogating 3 and 4-D datasets. The second application targets artists and enables them to construct new forms of complex curving 3D sculptures through direct manipulation with their hands. Both applications make use of multi-touch input, but in different ways. The first application uses an L-shaped multi-surface hardware arrangement (Figure 1) composed of a 4’x’3’ multi-touch table with a 9’x5’ vertical screen that provides an immersive view of the environment. The surfaces share an edge where they meet at a right angle. A complete report on this interface and application is described elsewhere [2]; below, we highlight two example interactions from the work that show how touch can be used in such an environment to perform complex 3D tasks with engineering data. The second application uses the same multi-touch table, but no vertical screen; the stereoscopic, head-tracked view is displayed on the table itself. In this example, touch interaction with the 3rd dimension is enabled by a different strategy, tracking the movement (e.g., tilt, rotation) of the hands just above the surface. A detailed description of several interfaces that can be constructed with this approach appears elsewhere [4]; below we highlight one interaction technique that enables artists to bend 3D surfaces with their hands in immersive VR.

Example Interaction 1: Path Planning in Anatomies
This interaction technique is used to specify a set of 3D points to build curves and generalized cylindrical volumes for the purpose of path measurements and surgical planning. The basic workflow can be seen in Figure 1 and Figure 2 shows a volumetric curve through the ascending aorta created with the interface. The interface uses a floating World-In-Miniature (WIM) for navigation. The current location in the environment is defined by a slice through the WIM, as indicated by the green line on the touch surface. 3D points are dragged out from the slice and positioned relative to the WIM using the Balloon technique [1]. Sequential points are built up to form a curve. Then, using an additional point of contact, usually the thumb, the curve is “inflated” at each control point to construct a volume.

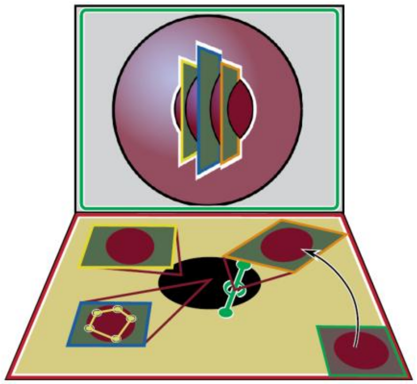

Figure 3. Persistent 2D slices capture a snapshot of a volume and using a convex hull gesture a volumetric selection is performed.

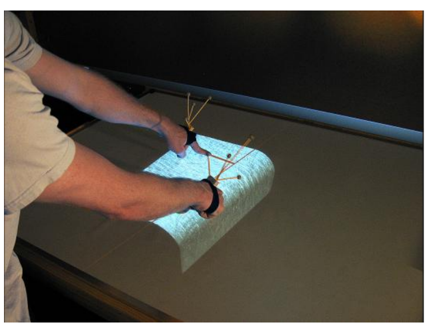

Figure 4. Using 6-DOF trackers attached to the hands, a surface fold is performed by defining a fold axis via 2D touch input.

Example Interaction 2: Rapid Volumetric Selection
This interaction technique, built on top of the same floating WIM interface, enables volumes of interest to be defined by touch input on several 2D slices through the volume data. The workflow is shown in Figure 3. As the user adjusts his location in the volume by using the slice indicated in green, a widget in the lower right corner is updated to display the 2D data slice through at this location. A persistent snapshot is saved by dragging out the slice from this widget. After a number of these are created, rapid volumetric selections are performed by placing several fingers on an individual slice and fitting a convex hull to them. The selection updates across all of the linked slices to include the portion of the volume outlined by this convex hull. In a vector of flow field, particle tracking is used to smartly extend the selection (e.g., extending along flow lines) throughout the volume.

Example Interaction 3: Artistic Surface Bending
Surface bending can be used as a 3D modeling technique to quickly form more complex shapes from flat surfaces (Figure 4). In this interaction, each of the artist's hands provides 6DOF input that is anchored through the use of 2D gestures on the workbench surface. Touching the surface with the thumb and index finger of one hand defines the center-line of the bend axis. A finger on the other hand serves as a clutch, locking the bend axis in place. By interpreting the 6DOF input of the first hand relative to the anchoring fingers, the artist can easily change the bending amount by pivoting her hand above the table. In this way, the artist can explore many bent shapes by moving her hands naturally through 3D space. Thus, the touch input, although anchored to a 2D surface, acts as a particularly expressive 3D input that includes not only touch on the surface but also 3D motions above the surface.

Domain Challenges and Guidelines

Support (New) Complex Tasks via More Immediate Gestural Interfaces
One of the most exciting opportunities provided by emerging touch technologies is the ability to explore styles of input that have not previously been possible (e.g., using many simultaneous touch points). In developing new interfaces, we should strive to go beyond replicating existing interfaces with touch wrappers and instead strive to enable new complex tasks with fluid and immediate gestures. For example, consider how different the interaction described in *Example 3* would be for an artist to perform using conventional 3D modeling software. Even a simple bend requires many vertex or control point movement operations. The immediate, real-time updates combined with physical action in the 3D touch interface are likely to more naturally fit the creative modeling process. Similarly, the volumetric selection in *Example 2* not only allows quick 3D lassoing, but also fluid immediate adjustment of the selection, qualities that are absent in current 3D visualization interfaces.

Use Smart Metaphors and Hardware to Avoid Hand-Occlusion Issues
An important design challenge in immersive touch interfaces stems from the problem of breaking the stereo illusion when one's hands block the view of virtual objects beneath. Some hardware-based solutions to this problem are possible (e.g., the multi-screen approach shown in Figure 1 alleviates the problem). Equally important is the use of smart interaction metaphors. For example, the slicing

metaphor used in *Examples 1 and 2* uses a shadow projection to ground the floating WIM to the horizontal table. Additionally the visual elements and colors that depict the slice through the WIM (Figure 2) are linked to the physical orientation of the screens, with red indicating a horizontal orientation and green a vertical orientation. The Balloon technique, employed in *Example 1*, is also a good example of a metaphor that helps to work around the hands occluding stereo touch problem. By interacting with a “string” attached to a 3D object above the table, the interaction technique avoids the situation where the hands and object are collocated and also has the advantage that the mapping between the hands and balloon is grounded to the physical touch surface.

Combine 2D and 3D Inputs and Visuals
One potential strength of immersive touch workbenches is their ability to easily mix and match 2D and 3D inputs and visuals. Too often we fall into a trap of limiting ourselves to one or the other when each presents its own strengths and weaknesses, instead we advocate for a more holistic approach. For example, the bending interaction described in *Example 3* demonstrates how both 6-DOF and 2D touch input can be combined effectively by anchoring 3D interactions to the tabletop. Similarly the visuals employed in *Example 2* make use of the tabletop as rich 2D organizational space that is linked to a detailed 3D view.

Conclusion
We have presented three example interaction techniques developed for new applications in engineering and art. We believe the success of these interactions points to the potential of combining immersive VR displays with multi-touch input. Although designing interfaces for this combination of technologies can be challenging, we argue that the results can be extremely rewarding, opening up new applications and new fluid styles of input that can be useful in fields as diverse as engineering and art. In designing such interfaces, three guidelines that may be valuable to follow are: *support (new) complex tasks via more immediate gestural interfaces, use smart metaphors and hardware to avoid hand-occlusion issues, and combine 2D and 3D inputs and visuals.*

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