

# Physical Presence – Palettes in Virtual Spaces

George Williams Haakon Faste Ian McDowall Mark Bolas  
Fakespace Inc., Research and Development Group

## ABSTRACT

We have built a hand-held palette for touch-based interaction in virtual reality. This palette incorporates a high-resolution digitizing touch screen for input. It is see-through, and therefore does not occlude objects displayed behind it. These properties make it suitable for direct manipulation techniques in a range of virtual reality display systems. We implemented several interaction techniques based on this palette for an interactive scientific visualization task. These techniques, the tool's design, and its limitations are discussed in this paper.

## KEYWORDS

Virtual Model Display, Spatially Immersive Display, Passive Props, Two-Handed Interaction, Bi-Manual Interaction, Magic Lenses, Physical Presence, Immersive Workbench, Immersive WorkWall, BOOM, Head-Mounted Display, CAVE



Figure 1. Left: original menu palette. Right: new analog palette.

## 1. INTRODUCTION

In previous work, we introduced a transparent, hand-held palette for virtual model displays [18]. We demonstrated how discrete, touch sensors on its surface augmented the interaction with 3D icons on virtual menus, Figure 1. We have recently constructed a similar tool which provides analog (x and y) input via a high resolution touch screen, Figure 1. Like the menu palette, the analog palette supports two-handed interaction and can serve as a prop for virtual controls. The introduction of a physical prop into the virtual space creates an interface with *physical presence*. The capability of analog input presents the possibility for novel interaction, which we explore in this paper.

### 1.1 State of the Art

A current trend in virtual reality is the use of large, stereoscopic, rear-projected displays. These displays encourage group collaboration and provide an ample, unencumbered working volume. For example, a

virtual model display uses a rear projected display to display stereo images of small models on a workbench or table top, see Figure 2. A spatially immersive display, like the Fakespace WorkWall, combines several rear-projected images along a wall to generate a life size virtual environment, see Figure 2 [5].

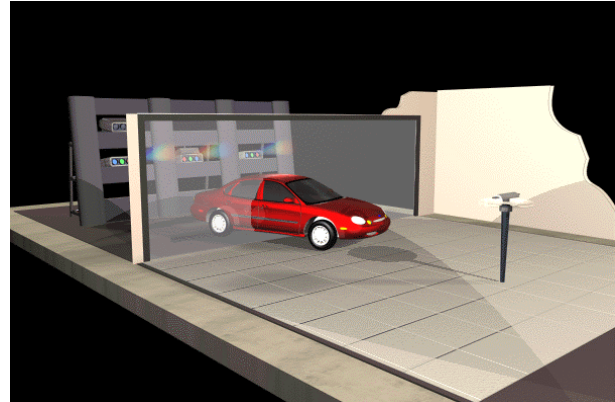


Figure 2. Left: users at a virtual model display. Right: a depiction of an Immersive WorkWall.

### 1.2 Human Factors

Advances in virtual reality have largely been technology driven. In recent years, a human-centered approach has occupied newer developments in this field. The basic theme of these developments is to make observations about how humans interact with their real environment, capture the salient properties of that interaction, and then transfer those properties to the virtual realm. In this way, we can create virtual experiences that leverage existing human skills and abilities. For example, it has been shown how the use of passive, real-world props aid in the pre-operative planning of neuro-surgical procedures [9]. Also, researchers have not only found that humans use two hands in many real world tasks, but also discovered that the use of both hands can improve virtual task performance dramatically over the use of one hand [8]. These two considerations, use of passive props and supporting two-handed interactions, were important design points of the tool we describe in this paper.

### 1.3 Passive Props

Props are familiar, real world objects. Just by the very shape and form of the prop itself, the prop can indicate how a task is performed. For example, Hinckley uses a doll's head and a plane tool for a brain visualization task, Figure 3 [9]. The plane tool oriented relative to the doll's head produces a clipped view of a volumetric brain scan in the display.

Perhaps the most compelling attribute of passive props is that they *are* just real objects. Real objects have weight, they have a tangible shape and form, and an overall palpable-ness; these kinesthetic qualities are noticeably absent in many 3D virtual users interfaces. In our experience, incorporation of some physical presence in the virtual interface leads to more natural interaction and builds on the user's expectations from the real world.

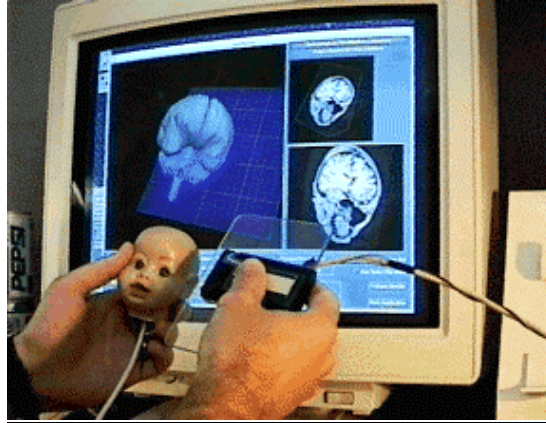


Figure 3. Hinckley's dolls head interface for neuro-surgical visualization

#### 1.4 Two-Handed Interaction

Most tasks in the real world involve the use of both hands working in concert. Many of these bi-manual tasks are also asymmetric in nature, that is, the non-preferred hand defines the coarse reference frame of the task, while the preferred hand performs the fine manipulation. Consider writing on a piece of paper or painting on a canvas using a brush in one hand and palette of paints on the other. Similarly, with the analog palette, one hand holds and positions the palette, while the other hand presses or glides across the touch screen surface.

## **2. RELATED WORK**

Touch screens and digitizing tablets have seen extensive treatment in the literature. Buxton has performed the most extensive evaluation of such devices [3]. Input Technologies combines a large display and touch screen in a workbench-style product for use with 3D modeling software [10]. Forsberg suggests using a clear touch screen or tablet input device with applications on the ErgoDesk, a virtual model display that supports 3D and stereo, but no head-tracking [7].

The artist's palette form has been used before as a metaphor for 3D interaction. Sach's 3-Draw uses a hand-held palette and pen-based input for 3D surface modeling in a non-stereoscopic, desktop application [12]. Stoakley's WIM uses a clipboard as a prop for hand-held miniatures in virtual reality using a head-mounted display [14].

Transparent user interfaces are not a new concept. Bier, et.al., implemented see-through tools for 2D software [1]. Viega, et.al, extended this concept to 3D, virtual environments [15]. Fraunhofer CRCG has implemented a palette-like, transparent tool for virtual model displays based on a pen and pad metaphor [12].

Hinckley presents a set of design issues for spatial input in [7], including the use of props and two hands. Buxton has also studied two-handed input extensively [4]. Cutler, et.al, has implemented a set of interaction techniques for virtual model displays based on two-handed interaction [6].

## **3. TOOL DESIGN**

### 3.1 Menu Palette

We used the metaphor of an "artist's palette" as the basis for the design of the original input device. Our first iteration was the *menu palette*, as depicted in Figure 4. Users hold the palette with their non-preferred hand, using the thumb hole for control. On the preferred hand, they wear a Pinch Glove [6]. The direct

contact between one of the gloved hand's fingers with one of the five conductive pads on the palette closes a circuit, generating a discrete event that can be caught in software.

The main palette body is composed of clear plastic and the conductive pads are transparent as well. Because of this, we can draw 3D graphics on the display and they will show up through the clear palette, see Figure 1. In a tracked environment, we can make it appear that small graphics objects are actually "attached" to the palette itself. The menu palette gets its name because we used the input capability of the palette to control virtual icons on a virtual menu "attached" to the palette.

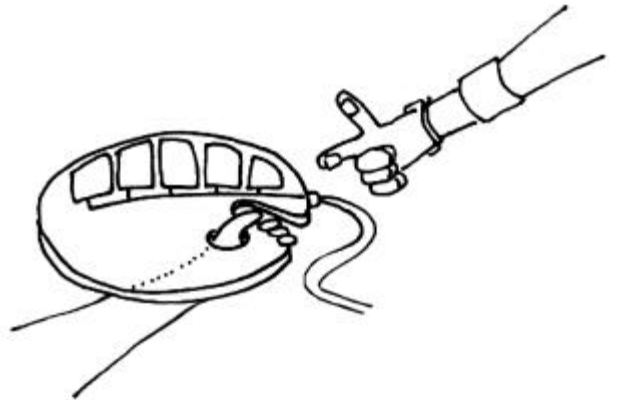


Figure 4. Depiction of the interaction on the menu palette.

### 3.2 Analog Palette

Like the menu palette, the design of the analog palette needed to take into account just a several different considerations, namely the tool's weight, hand grip, transparency, electrical wiring, and overall look. The actual touch-screen surface we used is the only prefabricated piece, and it consists essentially of a thin (1/16<sup>th</sup> inch thick) sandwich of 8" x 10" glass with a cord running out of the lower left hand corner. In the interest of keeping the tool light and transparent, we decided to frame this surface with a machined transparent acrylic support, rather than stick the pad on a thick (and heavy) clear acrylic panel as we had done in an earlier prototype. To hold the tool, we put a cylindrical grip down the left hand side of the tool, with a slot through the panel for the user's fingers to curl, see Figure 5.

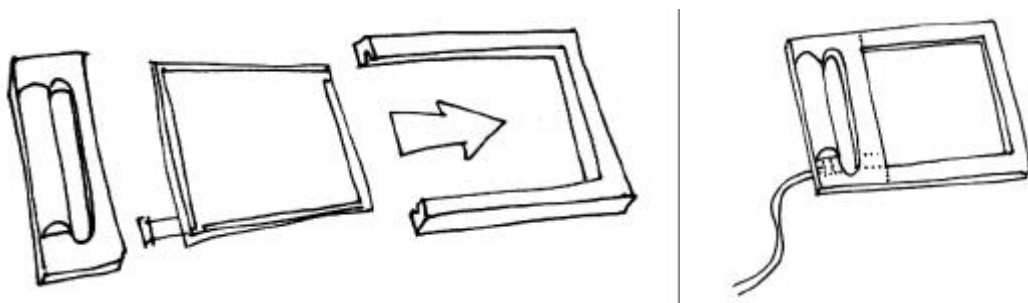


Figure 5. Left: exploding parts diagram of the analog palette. Right: completed palette.

An alternative design would have been to make the palette have a tennis racket-like paddle grip, but we wanted to discourage the temptation to use the tool too physically since its primary purpose is to execute precision tasks. The finished palette is easily disassembled, lightweight, and makes sense to the user as a 3D notepad-like device. The cord runs out of the tool near where the user's non-dominant hand holds the tool, and could potentially be run down the length of the user's arm. The palette's position and orientation are reported by a tracker attached to the acrylic frame, and we have tested the device with both electromagnetic and acoustic trackers.

## 4. INTERACTION TECHNIQUES

### 4.1 Interaction for Virtual Controls

The analog palette supports the same interaction techniques as the original menu palette for virtual controls. In addition to virtual buttons and virtual option menus supported by the menu palette, the analog palette can support analog-based controls like virtual pull-down menus and slider widgets. The implementation issues for virtual controls on the analog palette are similar to the menu palette and are not repeated here [18].

### 4.2 Interaction for Computational Fluid Dynamics

Scientific visualization uses computer graphics to create visual representations of complex and often massively large numerical data sets. Recent works have demonstrated how highly *interactive* computer graphics have benefited specific scientific problem domains, including the field of computational fluid dynamics (CFD) [2].

Wind tunnel simulations are a specific type of CFD simulation that can help researchers understand the behavior of air flow near surfaces. One time step in a wind tunnel computer simulation can produce a multi-dimensional volumetric data set that is far too complex to visualize at once. Because of this, researchers have developed techniques that enable viewers to selectively view portions of it. In the Virtual Wind Tunnel, users can interactively extract and view data along one spatial dimension, using streamlines and streaklines, or along two spatial dimensions, using iso-surfaces and contour surfaces, Figure 6 [2].

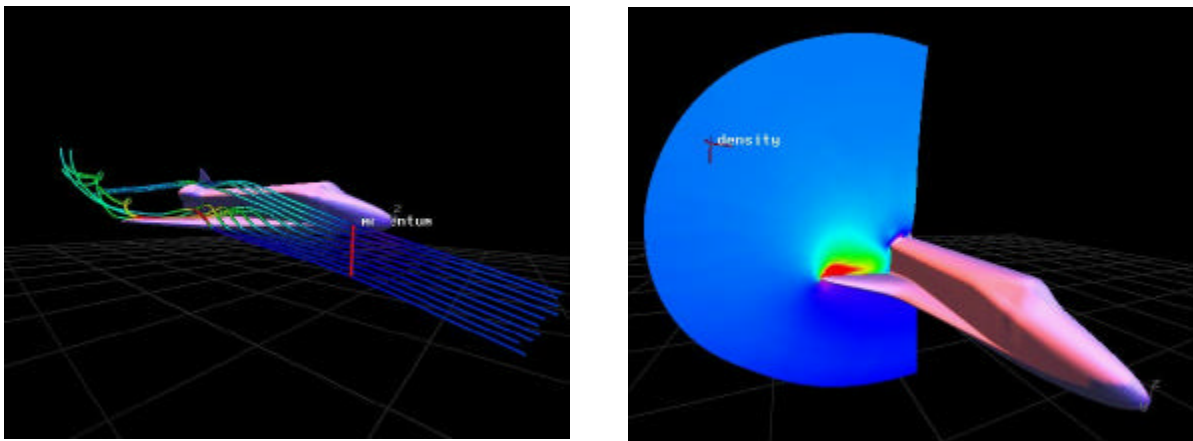


Figure 6. Left: streamlines in the Virtual Wind Tunnel. Right: contour plane in the VWT

The Wind Tunnel's virtual reality interface "immerses" viewers into the simulated flow field, as depicted in Figure 7. The stereoscopic and head-tracked view provides sufficient depth and parallax cues for directly interacting with the flow field. With a tracked hand gesture or 6DOF control like a Polhemus stylus, users can easily "seed" a streamline or position an iso-surface relative to the surface of the virtual model.

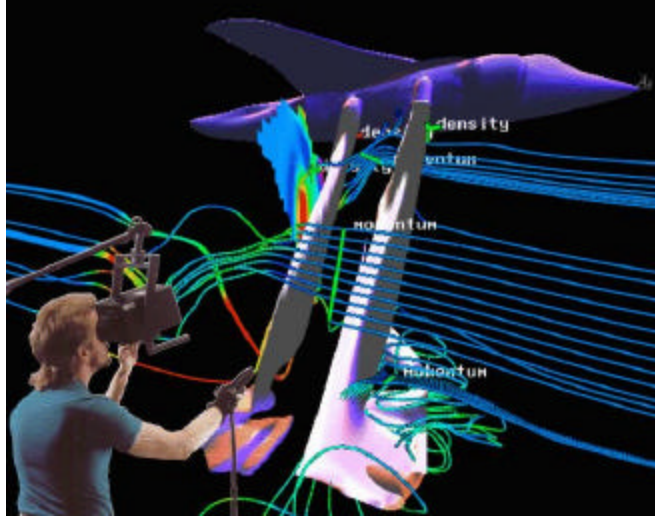


Figure 7. Depiction of Virtual Wind Tunnel immersion using a BOOM(3C)

We felt that the analog palette could improve the direct interaction in a virtual wind tunnel or similar CFD visualization in several obvious and novel ways. Firstly, the 2D palette surface could serve as a prop for the iso-surface and contour surface visualization objects. Secondly, the touch screen could be useful as a novel emitter source for streamlines or streaklines. Our implementation of these techniques is discussed below.

#### 4.2.1 Setup

Our setup used a very simple virtual wind tunnel data set of the space shuttle, and the Fakespace Immersive WorkWall for the display (see Figure 2.) The WorkWall blends three rear-projected images into a 22 by 9 foot image. We employed shutter-based stereo and tracked the head and the palette using Logitech ultrasonic trackers. Because the palette is translucent, viewers can see through the palette to the display. Users stood about 6 feet from the Wall.

#### 4.2.2 Palette as Prop for 2D Visualization Objects

Initial experiments with the palette demonstrated that the palette could serve as a prop for a cutting plane tool. This is depicted in Figure 8 for a fish-tank virtual reality system. (In a fish tank system, models appear to come out of the screen [17]. The effect is similar on a virtual model display and on the WorkWall.) Users quite naturally understand that the virtual model “in front” of the palette will always be clipped from view.

We also experimented with using a hand-held tracker or tracked stylus to control the clipping plane. We found that the palette-based interaction was easier to use. The reason, we surmised, was due to the physical shape of the palette, which provides a tangible *plane-of-action* that naturally maps to the software cutting plane. On the other hand, a hand-held tracker or tracked stylus suggests a *point-of-action* and therefore readily affords the positioning of the cutting plane, but not the orientation.

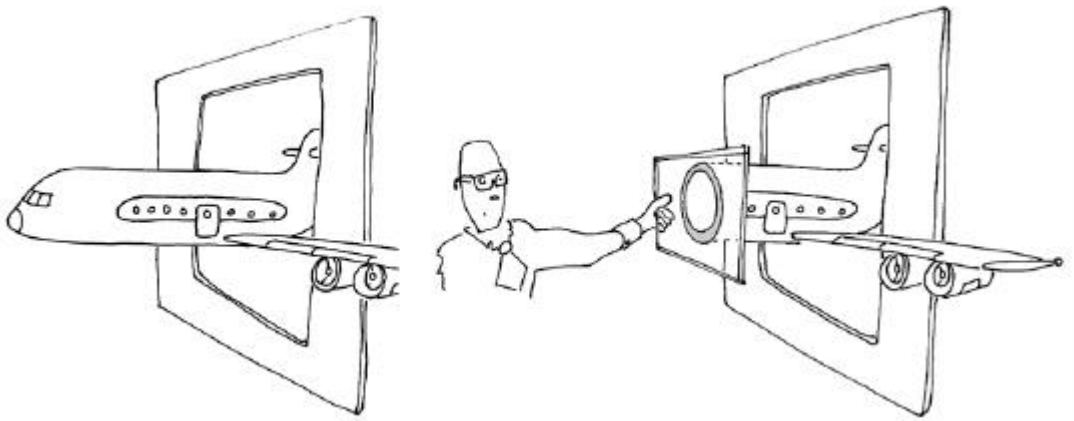


Figure 8. Palette as cutting plane tool.

Given the success with the cutting plane, we felt that the palette would be similarly useful for placing the 2D CFD visualization entities, the iso-surfaces and the contour surfaces.

#### 4.2.3 Palette as Emitter Source

The touch screen surface of the palette is very precise. The version we used had a 1000x1000 resolution over an 8 by 10-inch surface area. Much higher resolutions are also available. Because of this, the palette can serve as a very precise spatial input device. We experimented with the palette as an input tool for directly positioning “seed points” into the flow field. Seed points are the starting points for stream lines and streak lines. To place these seed points, users orient the palette as desired into flow field with their non-preferred hand, then touch the palette using the finger from the preferred hand to directly seed a streamline at the point of contact.

An interesting variation on this allows users to program an array of seed points on the palette. Users sketch a 2D pattern of seed points onto the palette surface then insert the palette into the flow field. The set of streamlines that emit from the pattern of seed points on the palette surface are computed. This set is recomputed as the palette is repositioned and reoriented in the flow field. This interaction is depicted in Figure 9. This interaction is useful when you want to see the behavior of the air flow at different locations given a constant set of stream lines.

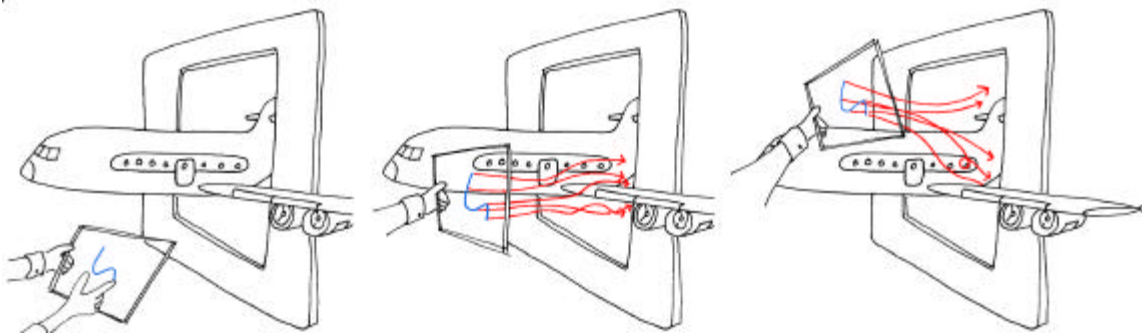


Figure 9. Palette as streamline source.

#### 4.2.4 Evaluation

We found that these palette-based techniques could offer a qualitative improvement over the present techniques to introduce 1D or 2D visualization objects into the simulation. However, we did not attempt to quantify this improvement or evaluate its usability under controlled experiments. Our intuition is that,

while these techniques are novel and visually appealing in many ways, they do *not* significantly improve the existing input methods. In other words, the existing techniques, 6DOF tracking or glove input, are quite adequate to perform those visualization tasks.

However, we did discover a new, useful interaction technique that uses the full expressiveness of the palette to perform a very useful task. In a virtual wind tunnel, one of the interesting challenges is to interactively explore the flow field close the virtual model's surface. Many of the most interesting and enlightening CFD phenomena can occur very close to the actual surface of the object in the flow field. Unfortunately, trying to follow a path along the virtual surface without any haptic feedback from the surface can be very difficult. To accommodate this task, we tried combining the function of the *palette-as-prop* clipping tool and *palette-as-emitter-source* input device. As depicted in Figure 10, users merely run a finger along the outside edge of the cross-section of the clipped model that appears on the palette surface. Because the palette *is* the clipping plane, users understand quite naturally that they are setting streamlines at or near the surface of the virtual model. Visual *and* haptic cues reinforce the performance of this task.

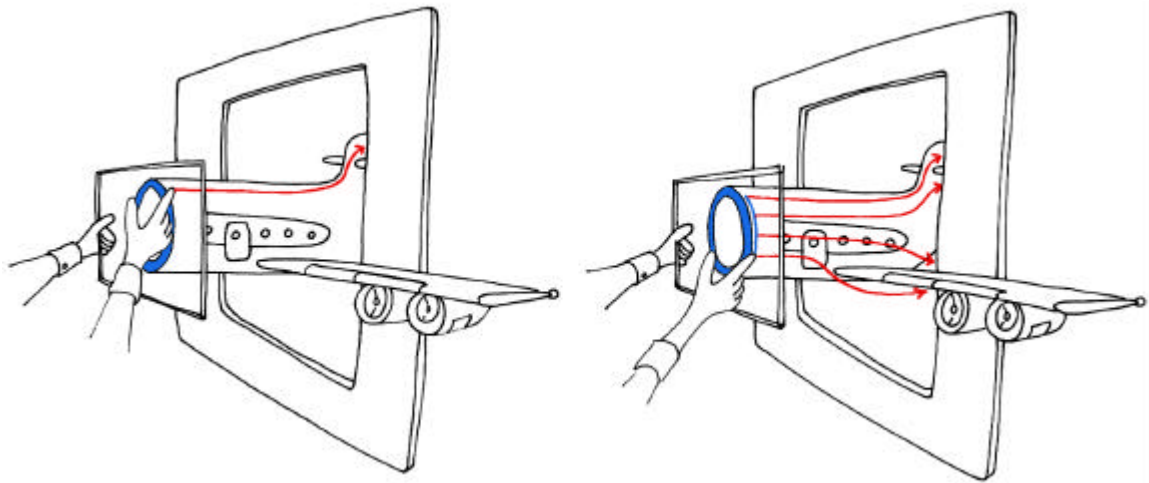


Figure 10. Palette used to set streamlines near surface.

The palette works well for this task because it is a compound task. This task requires the simultaneous placement of a plane in 3D (the cutting plane) and the placement of a point in 3D (seed point for streamline). A one-handed manipulation technique like a tracked stylus or glove would have to perform these sub-tasks sequentially and could not benefit from any haptic feedback.

Figure 11 and Figure 12 are snapshots of palette-based interactions on a WorkWall.



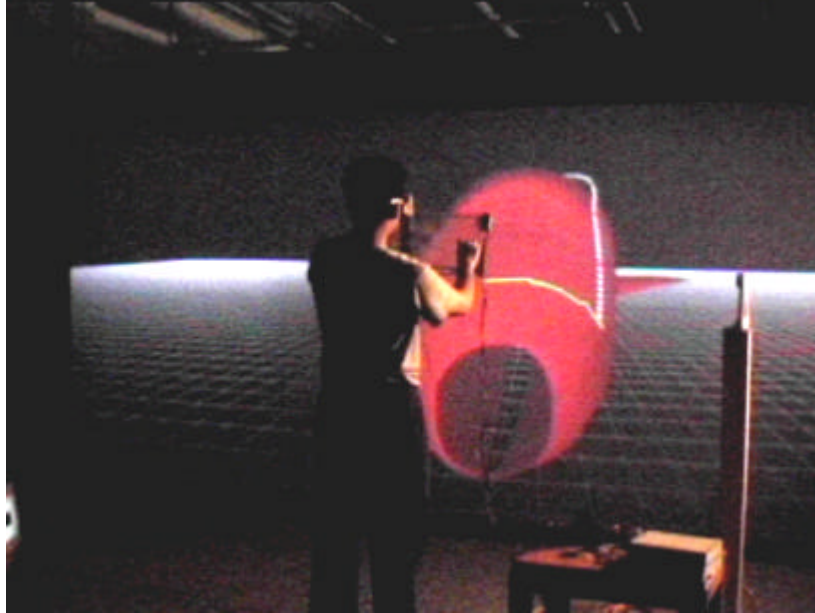


Figure 11. A user is exploring the flow field around the shuttle with one streamline. The nose of the shuttle is being clipped by the palette.

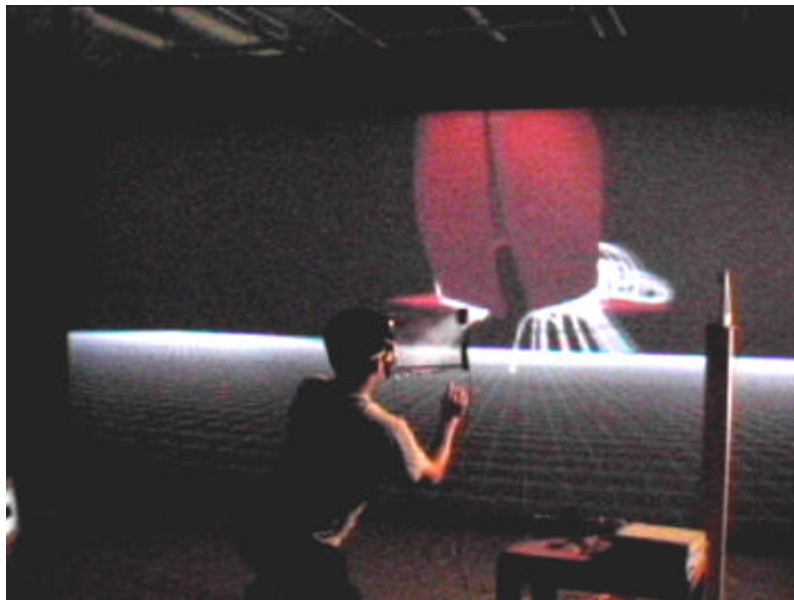


Figure 12. A user is exploring the flow field underneath the shuttle, close to a wing. In this interaction, several streamlines are seen at once.

## 5. LIMITATIONS

### 5.1 Conflicts of Perceptual Cues

The conflict between convergence and accommodation visual cues affects many stereoscopic display systems. The eyes can only accommodate (or focus the image) at the display surface, while at the same time, the eyes are continually converging on the perceived depth of objects in the scene (to fuse stereo pairs). Ideally, the eyes should converge and accommodate at the same distance. The *palpable* palette adds another potentially conflicting channel of perceptual information with kinesthetic cues.

## 5.2 Occlusion Artifacts

Occlusion is one of the most important visual depth cues for humans. Opaque artifacts between the user and display can cause incorrect occlusion relationships to emerge, since the real, opaque object can never be occluded by a virtual one. The palette is transparent and does not cause this problem. Unfortunately, the hands that hold and interact with the palette will demonstrate this unwanted effect.

## 5.3 Undesirable Optical Properties

The prototypes we built used touch screens that were translucent, but not completely transparent. This caused problems in areas where the display was not quite bright or had low contrast, or if the palette was too far away from the display. Future prototypes will take advantage of highly transparent touch screens, which are available at higher cost.

## **6. FUTURE WORK**

Many tasks in virtual reality might require a simple 2D constraint plane and analog input. 3D modeling and medical visualization are two application areas that we would like to explore possible uses of the palette.

It quickly becomes tiresome to hold the palette in free space. We would like to explore techniques for being able to clutch the physical tool in the working volume.

The tracking technology used to track the palette is typically less precise than the precision offered by the touch screen itself. This essentially limits the overall resolution of the input device to the resolution of today's 6DOF tracking technology. We would like to try mechanical tracking, such as that used by a BOOM arm, to possibly recover much of that lost resolution.

## **7. ACKNOWLEDGEMENTS**

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