ALTERNATIVE DISPLAY AND INTERACTION DEVICES

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ABSTRACT

While virtual environment systems are typically thought to consist of a head mounted display and a flex-sensing glove, alternative peripheral devices are beginning to be developed in response to application requirements. Three such alternatives are discussed: fingertip sensing gloves, fixed stereoscopic viewers, and counterbalanced head mounted displays. A subset of commercial examples that highlight each alternative is presented as well as a brief discussion of interesting engineering and implementation issues.

INTRODUCTION

For many, Virtual reality (VR) is synonymous with, and restricted to, goggles and gloves. VR was introduced to both the engineering community and the general public in this way and the image has been reinforced over time by trade journals and the press (Ref. 1). As Fig. 1 indicates, VR really is used to sell newspapers.

From Newsstands to Telephone Booth -- VR is Goggles and Gloves

Figure 1 Figure 2

This narrow definition is typical of a new field -- prejudgments are often made about a set of new technologies and ideas long before the technologies and ideas have a chance to evolve into useful configurations. The butler robot that will mix and serve drinks in the home has yet to materialize, but his non-humanoid cousins are busy building millions of cars.

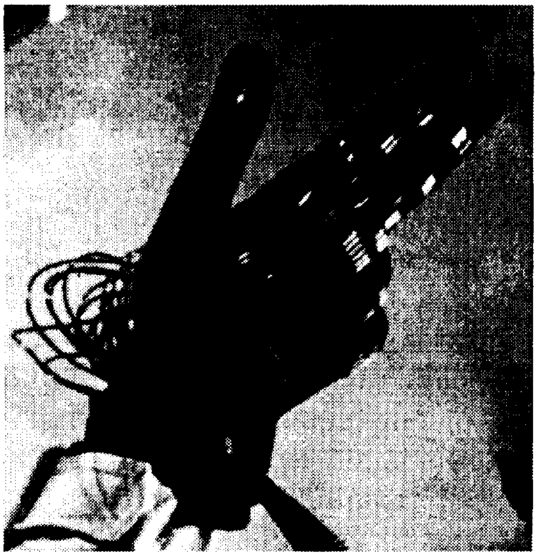
This paper highlights a subset of new technologies that are not dramatically different from the familiar goggle and glove approach. Instead, these new technologies represent innovations tailored for specific application requirements. Also discussed are the advantages and limitations of each and how applications have motivated the development of these approaches.

GLOVES

The standard glove input device used for VR applications is based on the flex-sensing design made popular by the VPL Dataglove™ (shown in Fig. 3). This device measures flex along the length of each finger and thumb via a proprietary fiber-optic bend sensor (Ref. 2). A number of these flex gloves based on different technologies are commercially available. Virtual Technologies produces a high-end glove that uses 22 precision strain gauge sensors. Mattel Toys sold hundreds of thousands of flex gloves for video game use. Their glove incorporated low-cost resistive ink sensors. Exos produces a device that consists of a mechanical exoskeleton that is attached to the hand and uses rotary encoders to determine finger flex.

Typically, a graphics workstation uses the data from a flex glove to drive a kinematic model of the human hand. The computer model of the hand is rotated at the knuckles to match the corresponding flex data at each knuckle sensor of the glove. In this way a geometric representation of the overall shape of the hand is displayed.

While many VR systems incorporate such an exact graphical representation of the hand, the primary requirement for most applications is to allow the human hand to naturally interact with a virtual world. This does not always require an actual display of the hand. It does require the shape of the hand to be analyzed to recognize gestures or postures of the hand, which are then interpreted as a user command. Popular postures include making a fist to 'grab' a virtual object or pointing with the index finger to 'fly' in the direction pointed. Dynamic shape recognition goes one step further to recognize moving gestures (Ref. 3).



VPL Dataglove
Figure 3

Fakespace Pinch Glove
Figure 4

Unfortunately, flex gloves have a number of limitations when used to detect the precise hand postures used to indicate user commands. Because hands differ in shape and size, flex gloves must typically be calibrated for each user. Some flex gloves require that this calibration be repeated over time, especially if the glove slips while on the user's hand. Researchers also report that flex gloves can have 'unintentional interdependencies among the sensors' and that 'the input data of two executions of the same gesture may vary widely because of the bad repetition accuracy' (Ref. 4).

If the only task is to record a user's six degree of freedom intent, then an obvious alternative is to replace the glove with a hand-held spatially tracked switch. The Simgraphics Flying Mouse™ is a commercial example of such a system. This and similar devices work well for certain applications and can be made more effective if a representation of the interaction device is itself represented in the virtual world (Ref. 5). Another alternative is to design the VR system to function without the need for hand interaction (Ref. 6).

Nonetheless, many applications would benefit from a device that allows for a natural representation of hand interaction. Such natural interaction does not require an actual graphical representation of the hand, but it does require the computer to recognize hand actions in a way that is consistent with the user's feelings of immersion (Ref. 7).

One way to accomplish this recognition of natural gestures is to sense contact between the fingertips. Fakespace's Pinch™ Glove (shown in Fig. 4) senses the completion of a conductive path between any of the fingers and the thumb. In this fashion a number of gestures can be recognized that have natural meaning to the user. Note that flex data are not required for gesture recognition, only simple binary information between the fingertips. For example, Fig. 4 shows a 'pinching gesture' that can be used to grab a virtual object, while a 'finger snap' between the middle finger and thumb can be used to initiate an action.

A natural representation of the hand not only allows for a rapid and intuitive assimilation of a user into an environment, but there is anecdotal evidence that it makes a user feel more 'grounded' in the virtual space, thus reducing the potential for nausea and disorientation. The Pinch Glove design works with different sized hands, requires no calibration and does not drift over time.

While fingertip sensing gloves have been postulated for some time (Ref. 8), the Institute for Simulation and Training (IST) was among the first to develop such alternative glove devices. IST's first implementation was a program called Polyshop that uses two spatially tracked fingertip gloves to enable the rapid construction and manipulation of simple polygon based geometry (Ref. 9). A compelling 'tangram' puzzle demonstration using Polyshop quickly proved the utility of the interface. The Toyscout organization at IST demonstrated a number of simple games that used opposing finger gestures to fire a weapon at an attacking enemy. The speed with which young users of the game were aiming, firing and then ducking, testified to the level of immersion consistent with this interface.

Fingertip sensing gloves could also be modified by:

- Adding force-sensing elements to each fingertip, thus allowing for analog force interaction with virtually grabbed objects.

- Adding flex-sensing elements to create a hybrid glove that adds hand shape representation to the fingertip sensing's quick and error-free gesture recognition.

- Using fingertip sensing elements in a hybrid glove to 'self-calibrate' flex sensors while the glove is in use.

- Adding a 'sensing work surface' to measure contact between the fingertips and the desktop, thus enabling interaction between the glove and worksurfaces such as a virtual desktop.

GOGGLES

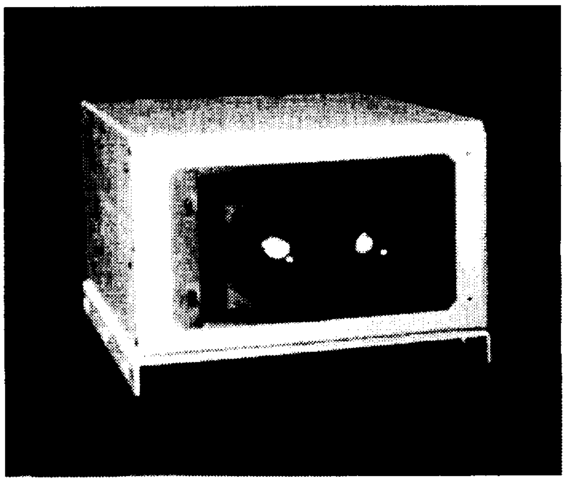
Virtual reality systems have created a strong demand for head mounted displays (HMDs). In the past five years these displays have evolved from expensive and heavy systems primarily fashioned for military training and simulation to lightweight and inexpensive systems designed for the home computer market.

Even with the advances made, few if any HMD systems meet the following three design goals: an 80 degree field of view or greater; more than 1 million pixels per eye and weight on the user's head of less than 10 ounces. This means that for the time being, the HMD is either going to be narrow, fuzzy or heavy - characteristics that detract from an immersive experience.

While many applications require the use of an HMD system despite their current drawbacks, not all do. For these other applications, alternative viewing systems can meet the three basic design goals outlined above while also providing an additional set of benefits. Interestingly, the two alternative systems presented here are based on configurations that existed before the modern HMD. These are the fixed stereoscopic viewer and the counterbalanced head mounted display.

Fixed Stereoscopic Viewers

Similar in many ways to the early nickelodeon display, an effective alternative to HMDs can be found in the fixed stereoscopic viewer (FSV).



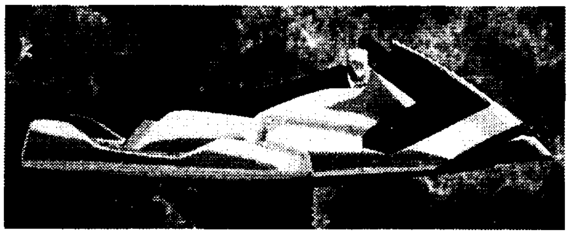
Fakespace Immersive Stereo Viewer
Figure 5

Telepresence Virtual Brewery Exhibit
Figure 6

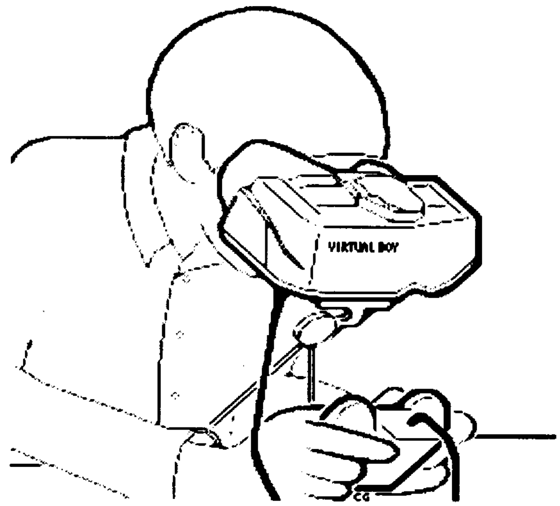
Because of the form factor, an FSV can meet the design goals outlined above. The Fakespace Immersive Stereo Viewer (ISV™) (shown in Fig. 5) offers over 1.2 million pixels per eye with a selectable field of view ranging from 30 to 100 degrees. Fixed displays of this type are naturally robust, economical and provide high user throughput. These qualities make the FSV ideal for a location based entertainment venue or other such public installation.

Figure 6 is an image from the Virtual Brewery project installed at the Sapporo Headquarters in Japan by Telepresence Research. This installation is comprised of twelve Fakespace Immersive Stereo Viewer systems coupled with a Fakespace BOOM3C™ display, an SGI Onyx™ computer and a Crystal River Acoustetron II™ (Ref. 10). While one patron uses the BOOM3C to navigate and control the point of view (POV) through a virtual brewery, twelve additional patrons can 'go along for the ride' by looking into the Immersive Stereo Viewers. This arrangement allows for over 1000 people a day to experience the virtual environment in an easy and comfortable way.

It is interesting to note that even though the user cannot use head motion to control the POV, the experience obtained with a fixed stereoscopic viewer can be quite immersive. It retains the feeling of a first person POV except that viewpoint changes are attributed to an overall shift of the frame of reference - almost like being a passenger in a vehicle. This is critical as it allows the user to feel grounded as opposed to nauseous.



Greystone Mercury Platform
Figure 7



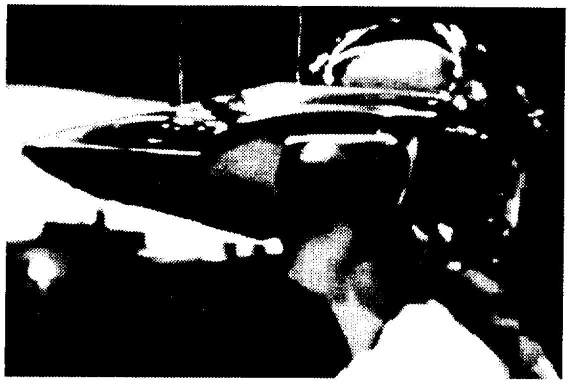
Nintendo Virtual Boy
Figure 8

Fixed stereoscopic viewers need not remain completely fixed. Greystone Technology recently released the Mercury Platform™. This system couples a Fakespace ISV display with an air powered three degree-of-freedom motion base and a modified motorcycle grip for navigation. Users of the system sit down in a fashion similar to a motorcycle and peer into the ISV display. As the user navigates through the virtual environment, the platform tilts and rolls to simulate motions corresponding to the action in the virtual environment. The fixed nature of the ISV works perfectly with the design of the overall system and takes advantage of the vehicle-based immersive feelings described above.

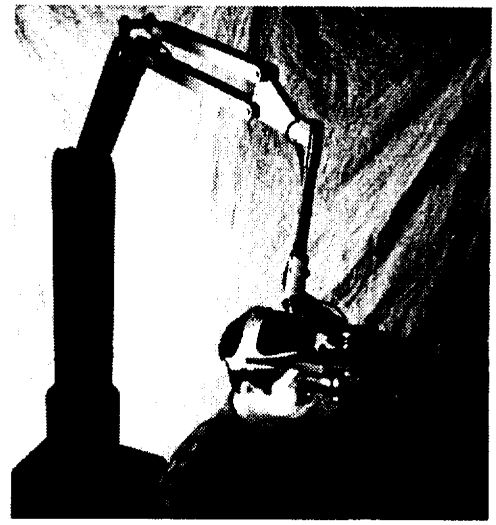
Perhaps the largest provider of FSVs will soon be the Nintendo Corporation. Nintendo has finished work on the Virtual Boy™ system that uses two monochromatic displays mounted in a table-top viewing system as seen in Fig. 8. The system was shown at the 1995 Winter Consumer Electronics Show and allows the user to control the immersive view via a hand-held controller while peering into the table-top stereoscopic display. Users have commented on the sharp images and high quality stereoscopic effect - qualities that the fixed display form factor easily achieves.

<u>Counterbalanced Head Mounted Displays</u>

Counterbalanced displays that are head mounted, as opposed to head coupled (Ref. 11), is the last alternative technology considered here. Counterbalanced head mounted displays have been used since the early days of computer simulation to achieve high visual and tracking performance without the limitation of weight constraints.



Disney Imagineering Aladdin Adventure
Figure 9



Fakespace FS2 Simulation System
Figure 10

Disney Imagineering has installed a CRT based stereoscopic display system at Epcot Center that is counterbalanced via an airspring and a pair of supporting cables (shown in Fig. 9). These cables ensure that the display cannot be dropped to the floor. The added weight made possible by counterbalancing allows for a rugged carbon-fiber shell that protects against public abuse. A detachable head strap increases the overall system throughput. Magnetic tracking is used as opposed to mechanical tracking due to the flexible nature of the cable counterbalance.

Fakespace produces the FS2™ Simulation System (shown in Fig. 10). The FS2 is a full six degree of freedom counterbalanced display and tracking system. The system uses lightweight materials and three independent spring counterbalances to minimize inertia and eliminate head supported weight. Noiseless mechanical tracking is achieved via optical shaft encoders while user-selectable optics achieve over a 100 degree field of view. The display attaches to the user via a head strap. The FS2 is optimized to be a seated simulation system with the automotive and simulation industries as early adopters. The system was designed to work well within the tight confines of an automobile interior. In particular, the head and structure are shaped to reduce potential interference problems with a vehicle's steering wheel, headrest and seat.

Counterbalanced head mounted displays are extremely comfortable because they exert no weight on the user's head - effectively they weigh zero ounces. This is important for many simulation systems where the operators may be immersed for hours at a time. Because of inertial effects, however, the mass of the displays and the distribution of the mass cannot be ignored. Both the FS2 and the Disney displays were designed to minimize mass without sacrificing display quality. As a result, the inertial effects are roughly the same as those for commercially available CRT based head mounted displays while maintaining fields of view of over 80 degrees with resolutions of more than 1.2 million pixels per eye.

CONCLUSION

Virtual reality has opened up a powerful and effective set of new techniques and technologies for delivering immersive experiences. As the science and art of designing these experiences matures, it becomes clear that the engineer and designer should look toward the constraints imposed by specific applications for guidance and insight. In many cases, the shedding of prior technical assumptions leads to tools that surpass expectations. The field of virtual reality is beginning to flourish with exciting and tantalizing immersive experiences and tools.

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