Usability of Multiple Degree-of-Freedom Input Devices and Virtual Reality Displays for Interactive Visual Data Analysis

Elke Moritz*
Mercury Computer Systems, Berlin, Germany
Thomas Wischgoll†
Wright State University, Dayton, OH
Hans Hagen‡
Technical University of Kaiserslautern, Germany
Joerg Meyer§
University of California, Irvine

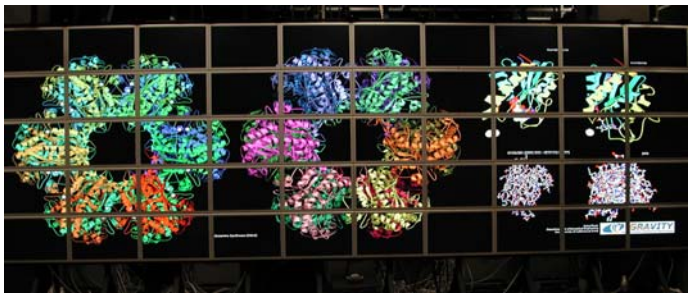

Figure 1: *HIPerWall display of Glutamine Synthease (2GLS). Comparison between MolScript and PyMOL rendering.*

Abstract

Interactive virtual reality applications commonly require two key technologies: multiple degree-of-freedom input devices, and 2D or 3D displays. The industry has developed a vast variety of devices for a growing consumer market. Consumer magazines regularly publish test reports for new devices. These reports are often focused on the gaming community, which is typically the driving force behind new product development. Although many lessons can be learned from the gaming industry, the scientific community is generally focused on other criteria, such as precision, degrees of freedom, and user tracking. It is expected that some of these criteria, which are currently in the state of research, will eventually be incorporated into products for a mass market, just like consumer graphics cards and certain input devices did in the past.

This study is an attempt to provide an overview of existing 2D and 3D input device and display technologies for interactive scientific visualization applications. Different types of input devices and displays were tested in combination with each other. The article explains why certain combinations of input devices and displays work together better than others.

CR Categories: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Input Devices and Strategies; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual Reality; J.2 [Computer Applications]: Physical Sciences and Engineering—Chemistry; J.3.2 [Computer Applications]: Life and Medical Sciences;

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*e-mail: moritz@siggraph.org
†e-mail: thomas.wischgoll@wright.edu
‡e-mail: hagen@informatik.uni-kl.de
§e-mail: jmeyer@uci.edu

1 Introduction

A large variety of input and display devices for Virtual Reality (VR) applications is available on the market. Categories range from simple, cost-efficient solutions targeted towards the consumer market to high-resolution, 3D display environments with high-precision tracking systems suitable for scientific applications. At the present time, high-quality Virtual Environments (VEs) have not entered the mainstream market yet, mainly due to the price tag associated with the necessary technology, or because of inadequate technology, which is not ready to stipulate customer satisfaction yet.

The purpose of this study is to provide an overview of existing technology and to identify combinations of input and display devices that have proven to work well together. The survey identifies features and limitations of each technology and explains why some input devices, even though they have, for instance, sufficient degrees of freedom, are not suitable for accomplishing a certain task, or how they can be replaced with other devices that may be more suitable or that make solving the given task more efficient.

Due to the large variety of input and display devices and constantly improving technology, this survey, as is the case with any other survey, can never be complete. However, our goal is to provide some guidelines for selecting the right combination of input and display devices for a given task, and to provide hints on how to avoid common mistakes. Ultimatively, by identifying current shortcomings in input and device technologies for virtual reality, we hope to also provide some guidelines for the design of new devices that will be-

	Buttons	Axes	Rumble/FF	DOF
Stylus	1	-	-	6
PINCH™ Gloves	Pinch	Pinch	-	6*
Mouse/Trackball	3	2	-	2 (3)
Joystick	8	2 (4)	FF	2 (3)
Nintendo64 Ctrl.	4 (14)	2	-	6*
Gamepad	10	7	Rumble	4-6
Steering Wheel	8	1 (2)	FF	1 (2,3)
SpaceGrips	3 each	-	-	6*
Phantom	1	3	FF	6

Table 1: *The number of buttons and axes of the input devices are listed in this table. Some devices are capable of providing force feedback (FF) or generated rumble feedback. The last column denotes the possible degrees-of-freedom (DOF). '6*' means that 6DOF are possible if an appropriate tracker is attached. In braces are the maximum numbers that can be reached through modifier keys etc.*

	Wireless	Hands	Users	Tracking
Stylus	No	1	1	pos+or
PINCH™ Gloves	No	1,2 both	1,2	pos+or
Mouse/Trackball	opt.	1	1	-
Joystick	No	2	1	mounted
Nintendo64 Ctrl.	No	1,2	1	pos+or
Gamepad	Yes	2	1	-
Steering Wheel	No	2+feet	1	mounted
SpaceGrips	No	1,2	1,2	pos+or
Phantom	No	1	1	mounted/incl.

Table 2: *Is the device wireless, how many hands are needed for interaction, can the device be shared by several users for multi-user interaction, is position or orientation tracking possible or integrated or is the device mounted at a fixed location. Electromagnetic tracking systems like Flock of Birds® or Polhemus FASTRAK® use cables.*

come useful in virtual environments in the near future.

2 Multiple Degree-of-Freedom Input Devices

Navigation and data analysis tasks in virtual reality environments often require multiple degree-of-freedom user interaction. Six degrees of freedom (6dof) are commonly used to implement this. Not all applications incorporate all six degrees of freedom, and therefore input devices with less degrees of freedom might be more appropriate for the specific task.

Tables 1 and 2 provide an overview of various properties of selected input devices. It should be noted that not all input devices provide all features listed in the tables. The following paragraphs provide some more detail information about each individual device.

In summary, we found that current input devices have the following features and limitations:

- Most 2D input devices are of very limited use when incorporated in a 3D virtual environment. Typical workarounds, such as pushing a button on the device or a modifyer key on the keyboard are usually cumbersome and not very intuitive.
- Current 3D or multiple-degree-of-freedom input devices, such as gamepads, are often a collection of 2D input devices (joysticks, 2D digital pads, etc.)
- The discrepancy between hand motion and visual feedback (hand-eye coordination) seems to work well in a 2D environment, but requires a much harder learning process in 3D and therefore should be avoided.
- 3D input devices should be wireless and not mounted to a table to enable the user to roam about freely in a 3D virtual environment.

We envision that these guidelines will help in the development of future input devices for 3D virtual environments.

	2D	3D	STEREO ready
CRT	x	–	*
Workbenches & Co	x	x	x
Tiled LCDisplay	x	*	–
Multi-Projector Tiled Display	x	x	*
CAVE™	x	x	x

Table 3: *Some display systems are suitable for 2D, some for 3D, some support STEREO: x means applicable, – not applicable, * depends on hardware setup.*

3 Display Systems

Display systems can be categorized into two groups: monoscopic and stereoscopic systems. Both environments can provide the user with a virtual depth perception and, if certain criteria are fulfilled, may immerse the viewer in a virtual world. The degree of immersion depends on the display type, the display size, the projection method, the resolution of the display, and the nature of the information to be visualized. In general, a large display size tends to immerse the user more than a small one, and it allows several users to collaboratively investigate virtual models.

We have tested a variety of display systems for several virtual reality applications. Table 3 summarizes the capabilities of the tested display devices.

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