A Prototype System For Synergistic Data Display

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Abstract

Multimodal interfaces have been shown to increase user performance for a variety of tasks. We have been investigating the synergistic benefits of haptic scientific visualization using an integrated, semi-immersive virtual environment. The Visual Haptic Workbench provides multimodal interaction; immersion is enhanced by head and hand tracking, haptic feedback, and additional audio cues. We present the motivation, design and implementation of the prototype system and describe some challenges ahead in the context of questions to be answered. Preliminary results indicate that visualization combined with haptic rendering intuitively conveys the salient characteristics of scientific data.

1 Introduction

A primary advantage of haptic interfaces is that they provide bidirectional interaction via position sensing and force feedback, thereby utilizing additional sensory channel bandwidth of the user. By combining haptic rendering and semi-immersive visualization, we hope to increase intuitive understanding of scientific data. For this purpose, we have designed and implemented a prototype testbed system, the Visual Haptic Workbench (see Figure 1). Using this system, we are investigating the synergistic benefits of combined visual and haptic scientific data rendering.

We desire an integrated environment capable of *bounded error interaction*, where a unified error tolerance describes the total system error throughout the workspace. Such a goal requires careful consideration of hardware components for performance, integration, and extensibility, a modular and efficient software infrastructure, and robust calibration and coregistration techniques. As a preliminary evaluation of the system, we experimented with synergistic rendering methods for a variety of scientific visualization applications.

2 Motivation for Design

Research on virtual workbench environments and haptics has produced many interesting results. Several applications of haptics to scientific visualization are relevant to the development of our system, including projects at UNC Chapel Hill, CSIRO, the University of Tsukuba, and the University of Boulder. In addition to these integrated systems, there are several relevant research publications on combined haptic and visual rendering techniques. The Visual Haptic Workbench [1] is a testbed system for investigating the possibilities of synergistic display of scientific data.

Building a multimodal system for synergistic display of scientific data involves three broad implementation issues. *Calibration* increases workspace accuracy to provide faithful data rendering while avoiding conflicting perceptual cues. *Coregistration* methods fuse multiple calibrated workspaces to accommodate their relative location, orientation, and scale. *Compensation* for communication and computational delays maintains interactivity and maximizes user performance. Achieving bounded error interaction requires careful consideration of solutions to these issues.

We also considered specific research applications to pursue with this system. At the SCI Institute, a variety of datasets are routinely investigated. These datasets vary in modality, size, grid type, and may be static or dynamic. Considering these demands, our system infrastructure must be efficient, modular, extensible, and scale well with data size.

3 State of the Prototype

We have constructed a prototype system consisting of a SensAble PHANToM 3.0 mounted in a T configuration above a Fakespace Immersive Workbench (see Figure 1). The PHANToM is suspended above the workbench with a cross-braced lumber frame. A redundant safety mechanism protects the user during operation. The dominant hand of the user experiences haptic feedback from the PHANToM, and the subdominant hand navigates through a menu interface via Pinch glove contact gestures. A Polhemus Fastrak is used for head and hand tracking, and an audio subsystem provides reinforcing sound cues. Finally, the Immersive Workbench provides a semi-immersive, virtual view for the user based on the tracked head location.

To support our initial investigation, we designed and implemented a software framework for application development on the Visual Haptic Workbench. Our software libraries contain haptic rendering methods, general VR support for immersive environment rendering and interaction, visualization methods, interface widgets, dataset classes, menu functions, and geometry tessellators. These software libraries are realized as runtime daemons and application threads, which communicate via shared memory data models and UDP messages. To maintain interactive update rates, these processes run concurrently on an SGI Onyx2 with 250 MHz R10000 processors and InfiniteReality2 graphics.

Figure 1. The integrated system prototype.

4 Challenges to Meet

There are several areas of improvement for our system. We briefly consider the following key issues:

- **Scalability and Interactivity:** Our initial applications have been able to maintain interactive visual framerates and haptic updates of 1kHz. With increasing dataset sizes, we hope to leverage parallel computation and distributed data models to ease the burden of data glut.
- **Quality of Haptics:** Our current system has 6DOF sensing and 3DOF force feedback, which can be a problem for applications where 6DOF is required for natural interaction. The precision of haptic control, bandwidth required, and kinematic calibration are issues to solve to improve the haptic performance of our system.
- **Display Accuracy:** Our current display consists of an analog CRT projector, rear surface mirror, and nonlinear diffusion surface. These characteristics limit the possible calibration and visual performance. Upgrades in progress include a front surface mirror and a new diffusion material with superior viewing properties.
- **Tracking Accuracy:** We have developed methods for quantifying and correcting magnetic tracker distortion and incorporated them into our prototype [2]. In addition, we are actively evaluating new tracking technologies as candidates for a system upgrade.
- **Overall System Coregistration:** Although our current coregistration methods are somewhat ad-hoc, we are developing methods to calibrate and coregister the system workspaces more precisely.

5 Questions to Answer

The Visual Haptic Workbench project was motivated by our desire to answer the following compelling questions:

- What constitutes a truly synergistic interface and how do we quantify user performance for the system?
- What specific factors contribute to the synergistic combination of haptics and visualization?
- What can we achieve with different CHI paradigms?
- How accurately can we engineer our system towards our goal of bounded error interaction?

We believe that our prototype system will provide the basic infrastructure for pursuing this future work. Preliminary results based on informal user evaluation indicate that the Visual Haptic Workbench is an effective tool of discovery for the exploration of scientific datasets.

Acknowledgements

Support for this research was provided by ARO DURIP grant DAAG-559710065, the DOE Advanced Visualization Technology Center (AVTC), and NSF Grant ACI-9978063.

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