Initial Haptic Explorations with the Phantom: Virtual Touch Through Point Interaction

by

Thomas Harold Massie

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Signature of Author...
Department of Mechanical Engineering
January 19, 1996

Certified by ....
J. Kenneth Salisbury, Jr.
Principal Research Scientist
rvisor

Accepted by...
Ain A. Sonin
Chairman, Department Committee on Graduate Students

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ABSTRACT

The primary topic of this research was the implementation and programming of a force reflecting haptic interface, known as the PHANToM (Personal Haptic iNTerface Mechanism). The goal was to develop software models that would allow users to feel and manipulate the data represented within computers. Compact models of texture, shape, compliance, viscosity, friction, and deformation were implemented using a point force paradigm of haptic interaction. The motivation for and implications of a point force haptic interface are discussed in detail. Finally, for those who are not immediately convinced of the utility of enabling humans to interact with computers through the sense of touch, a few of the applications enable by the PHANToM are described.

Thesis Supervisor: J. Kenneth Salisbury, Jr.
Title: Principal Research Scientist

Table of Contents

1. Introduction

This thesis addresses the design, programming, and implementation of a haptic interface designed solely with the intent of facilitating human-computer interaction. The Personal Haptic iNTerface Mechanism (PHANToM) uses a novel thimble-gimbal to achieve a "point force approach" to haptic interaction. Chapter 2 is dedicated to describing this approach as it has many implications for human perception and software development. Chapter 3 addresses the basic software issues, and Chapter 4 describes the applications for this particular haptic interface. Finally, Chapter 5, describes why point force haptic interfaces like the PHANToM will soon see wide use.

1.1 Haptic Interfaces

Real-time, photo-realistic 3-D computer graphics, and even spatialized 3-D sound are now achievable on high-end computer workstations. At the current pace of computer technology, few would argue that computer generated graphics and sounds, virtually indistinguishable from the real world they mimic, will be available on the personal computer within a few years. Visual and auditory feedback alone cannot enable a person to interact with the computer as naturally as he would interact with his real environment.

A significant component of our ability to visualize, remember, and establish cognitive models of the physical structure of our environment stems from haptic interactions with objects in the environment. Kinesthetic, force and cutaneous senses combined with motor capabilities permit us to probe, perceive and rearrange objects in the physical world. Information about how an object moves in response to applied force and the forces which arise when we attempt to move objects can provide cues to geometry (shape, locality, identity), attributes (constraint, impedance, friction, texture) and events (constraint change, contact, slip) in the environment [17].

In the course of a typical human computer interaction, a user views output on a video monitor, and works to change the input via a mouse, joystick, or keyboard. In general, human beings do not interact with the world this way. Rather we use our hands to both **change** *and* **measure** our environment. Imagine an artist molding clay, a jeweler fixing a watch, or a surgeon searching for a bullet through a small incision. These activities involve such an immediate level of manual interaction that they are not easily described in terms of "input" and "output". Unlike other sensory modalities, haptic interactions permit two-way interaction via work exchange. Controlled work can be performed on dynamic objects in the environment and modulated to accomplish tasks. Today, haptic feedback is woefully missing from the typical human computer interaction.

In that it was designed solely for human-computer interaction, the mouse is a unique exception among the list of human-computer interfaces. Consider the keyboard (typewriter), the cathode ray tube (television), the joy-stick (rate controller), and audio speakers (telephone receiver). All of these devices existed long before computers were attached to them, and arguably, only incremental improvements to these interfaces have been achieved. Haptic interfaces pre-date computers as well. Force-reflecting teleoperators were used to give humans a sense of presence in remote or dangerous environments long before they were attached to computers. The first computerized haptic interfaces were teleoperators, interfaced to computers which simulated the remote environment virtually [3]. In fact, some of the commercially available haptic interfaces today like the Sarcos Arm [25] and the Cybernet Per-Force [7] are teleoperator master controllers adapted for use in virtual environments.

In contrast to these earlier haptic interfaces, and analogous to the development of the mouse, haptic hardware and software algorithms with the specific goal of improving human-computer interaction are now under development. Some of the first efforts to build hardware designed specifically for enabling people to touch virtual environments was done at the University of California, San Diego in 1976 [2] and by Noll [21]. For a comprehensive reference of haptic projects see the bibliography provided in Margaret Minsky's thesis [18].

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