# Information and Energetics in Haptic Interaction

*J. Edward Colgate and Paul A. Millman*

Department of Mechanical Engineering
Northwestern University
2145 Sheridan Rd, Evanston IL 60208

**CONTACT INFORMATION**
Prof. Ed Colgate/ Paul A. Millman, R.A.
Northwestern University
Department of Mechanical Engineering
2145 Sheridan Rd., Evanston, IL 60208
Tel: (708)491-4264
Fax: (708)491-3915
E-mail: colgate@nwu.edu

**WWW PAGE**
http://apo.mech.nwu.edu/

**PROGRAM AREA**
Virtual Environments

**KEYWORDS**
Haptics, Perception, Virtual Environments, Dynamic Simulation, Stability, Training

**PROJECT SUMMARY**
We conducted an experimental investigation of human haptic perception and manipulation, with the purpose of understanding the roles of perceptual information and mechanical constraint when performing tasks with hand tools. We performed two experiments on human subjects. The first experiment involved detecting a haptic feature and moving to a target position. The second involved only the detection of haptic features.

Experiment I was an investigation of the relationship between step changes in environment damping and the performance of a Fitts one-shot tapping task. The task was performed using a one degree-of-freedom haptic interface. In the experiment, subjects were asked to move the handle of a haptic interface as quickly as possible to a narrow target region that had a different level of viscous damping than the background regions. The location of the target varied randomly from trial to trial. Damping levels in the target and background regions were systematically varied, and movement times were recorded as a measure of task performance. Performance was presumed to be determined by *perception* of the target (either haptic or visual), and also in part by mechanical *constraints* provided by the step changes in damping.

In the main experiment, the position of the handle was visible to subjects (in the form of a cursor on a screen), but *the target was not visible*. Two variations on the main experiment were conducted in which these visual feedback conditions were varied. In the first, both handle position and target position were visible, and in the second, neither handle position nor target position were visible.

The most striking result of the experiment was that when the targets were *not* visible to subjects, performance was very closely correlated with the absolute magnitude of the difference in target and environment damping (i.e. target damping minus the background damping). Performance did not vary with the percentage difference between target damping and background damping, nor with the sign of the difference between target and background damping, nor with the level of background damping. When target positions *were* visible to subjects, performance depended very weakly on the environment damping.

Performance of the task seemed to depend more strongly on (haptic) perception of the targets than it did on constraints, or energy, provided by the environment, although some results indicate that mechanical constraints made the task easier to perform.

Finally, visual feedback of target and handle positions resulted in performance that was always better than haptic feedback alone. However visual feedback alone (no haptic information or constraint) was only marginally better than the best haptic-feedback-alone case.

While Experiment I involved subjects performing an action (moving to a target position) based on haptic perceptions of the environment, Experiment II was concerned strictly with haptic perception. In Experiment II subjects performed a two-interval forced choice detection task. A single feature (or “bump”, or non-uniformity) was displayed in the environment, and subjects were asked to identify which half of the environment the feature was in (i.e. the left half or the right half). The non-uniformities in the mechanical impedance of the haptic interface were constructed of piecewise linear force vs. displacement curves, that is, stiffnesses.

As subjects moved the handle of the haptic interface, they experienced forces that varied because of the inherent dynamics of the device and "noise" in the force output of the device. The haptic features had to be detected against this background impedance and noise. This was possible because the features produced characteristic force transients as subjects moved over them. The main characteristic of the "bumps" that determined their detectability was the magnitude of the transient in the handle force. Neither the

width (physical extent) of the bumps nor the stiffness (rate of change of force with displacement) of the bumps strongly influenced their detectability. This indicated that the precise temporal aspects of the force transients were not as important to detection as the magnitudes of the transients.

Gravitational and spring-like background forces were added in some cases to see how they masked the haptic features. For all but the widest bumps, the background forces had no affect on bump detectability. This was interesting because in *static* force discrimination experiments, the ability to discriminate between two forces degrades as the magnitude of the two forces increases. So subjects must not be using static force difference as a primary perceptual cue. These results demonstrated that the temporal aspects of the stimuli *were* important.

## PROJECT REFERENCES


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## AREA BACKGROUND

In our research, we are concerned with developing technology which will allow persons to interact with virtual environments through the modality of touch, also called haptics. The primary challenges of this endeavor are the development of haptic interface mechanisms, and development of software simulations of physical systems for haptic display. A fundamental understanding of haptic perception is essential for informing the development of these hardware and software systems.

Many haptic interface design issues are closely related to issues in robotics, particularly telemanipulation and man-in-the-loop systems. Software design issues are informed by the disciplines of dynamic systems modeling and computer simulation.

Haptic interfaces are designed to generate controlled forces on users hands, which makes the haptic modality unique in that it typically involves significant exchange of energy (in this case mechanical energy) between a user and the interface. The additional requirements on simulations for haptic interaction, as opposed to non-energetic forms of computer interaction, are very significant. Simulations must run in real-time, and must be reasonably free from possible instabilities in order to ensure the safety of users. Additionally, most mechanical environments of interest involve events which occur on very small time scales (i.e. milliseconds) so that reasonable performance of simulations requires time steps on the order of 1 millisecond. These challenges are substantial, and unique to the problem of virtual environment simulations for haptic interaction.

## AREA REFERENCES


*Proceedings of the ASME International Mechanical Engineering Congress and Exposition (previously known as the Winter Annual Meeting) – Annual Symposium on Haptic Interfaces*, 1993 – 1995.


Many of the researchers in the field have World Wide Web pages that can be reached via links on our Web page (address listed above).

## RELATED PROGRAM AREAS

3 Other Communication Modalities
4. Adaptive Human Interfaces
6. Intelligent Interactive Systems for Persons with Disabilities

## POTENTIAL RELATED PROJECTS

The research that was conducted with the support of the Interactive Systems Program was focused on developing an understanding of haptic perception and the mechanics of haptic interaction. Other work in our laboratory relates to the development of hardware and software systems for realizing virtual environments with haptic feedback. As these engineering problems are solved, the technology will need to be integrated with other virtual environment systems, and other modalities of sensory feedback. The development of integrated systems may be a fruitful area of collaboration.

In addition, applications for haptic interface technology must be further explored. Possibilities include training, virtual prototyping, virtual environment navigation, computer music, and rehabilitation.