Hand Held Force Magnifier

Isometric Low Force Control and Superviscosity Experiments

R. Lee[1], M. Luo[1], C. Wong[1], P. Gershon[2], R. Klatzky[2], G. Stetten[1,3]

[1] Department of Bioengineering, University of Pittsburgh, Pittsburgh, PA; [2] Department of Psychology, Carnegie Mellon University, Pittsburgh, PA; [3] Robotics Institute, Carnegie Mellon University, Pittsburgh, PA

Abstract: The Hand Held Force Magnifier (HHFM) is a novel surgical tool that aims to enhance the surgeons' ability to perceive tissue properties during delicate surgeries. A sensor measures the tool-tissue interaction force, and an actuator generates proportionally larger forces onto the handle of the tool, which is gripped by the user. As a result, forces at the tool tip are perceived to be magnified. Potential applications of the HHFM are vascular surgery, cataract surgeries, and neurosurgeries. We present here psychophysical experiments that characterize human behavior while holding small forces, and investigate how feedback forces can control user dynamics following membrane puncture.

Isometric Low Force Control

Introduction: A common scenario in microsurgery is the need to maintain very small forces over time, for example, during membrane peels. Psychophysical experiments will quantitatively describe human behavior near the limits of tactile perception, and the extent to which this behavior is altered by the HHFM.

Methods: The magnitude and direction of the target forces, as well as the HHFM magnification state, are randomly selected by custom-built hardware. LEDs initially guide the subject toward the target force, but this visual feedback is removed 2 seconds after first reaching the target force. The applied force is continuously recorded using a high precision reference sensor.

Figure 1. Experimental Platform

Results:

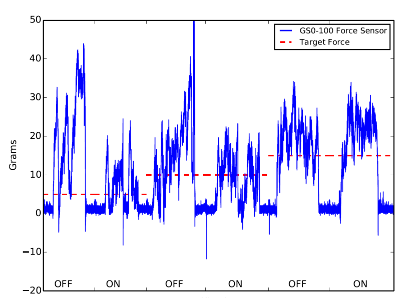

Figure 2. Tool tip force for 5, 10, 15 g (49, 98, 147 mN) in push direction

Conclusions: Preliminary results demonstrate that, by augmenting the perception of the tool-target interaction, the HHFM can improve the user's control over small forces.

Superviscosity

Introduction: Previous psychophysical studies have shown that magnified forces produced by the HHFM are perceived similarly to real forces of equal magnitude. This can be detrimental to user performance when puncturing a membrane above a sensitive substrate, as the natural tendency is to generate larger forces in the arm to match the perceived force.

Methods: Membranes of varying stiffness are generated using a Magnetically Levitated Haptic Device (MLHD), a machine that can apply forces and torques onto a pen-like tool in 6 DoF over a 24 mm diameter space. By recording tool position and velocity, we can investigate how velocity-dependent feedback forces alter user behavior. These "superviscosity" forces are governed by the following function,

$$F = Av^3 + Bv$$

where *A* and *B* are scaling constants, and *v* is the tool velocity.

Results: We characterize user behavior by calculating two parameters from a generalized model of post-puncture behavior: "deviation point," the time point at which user position diverges from predictions; and the "zero crossing," the first time point where tool velocity is zero.

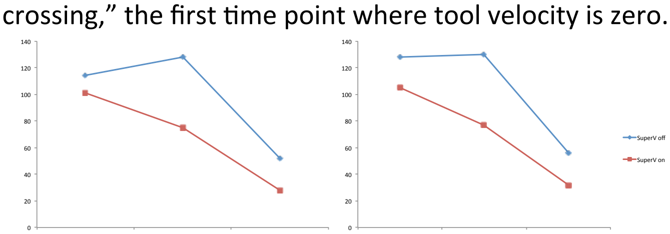

Figure 3. (L) Deviation point with/without superviscosity; **(R)** Zero crossing with/without superviscosity

Conclusions: Preliminary results suggest that superviscosity can reduce the time delay before users regain active control over the tool, potentially reducing the distance traveled post-puncture.