Visualization and Image Analysis Laboratory

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Hand Held Force Magnifier (HHFM) Isometric Low Force Experiment

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Abstract: The lack of sense of touch presents a difficult challenge for surgeons performing microsurgery, as in vascular surgery or ophthalmology. To augment the surgeons' perception of tissue properties, such as stiffness and viscosity, we have been developing a novel surgical device, the Hand Held Force Magnifier (HHFM) [1]. A sensor in the HHFM measures the interaction force between the tool tip and the handle, while an actuator amplifies the measurement to produce a proportionally greater force in the user's hand [2]. As a result, the forces at the tool tip are perceived as magnified. The clinical applications of the HHFM include, but are not limited to, the repair of tiny blood vessels that are too delicate to be felt by the surgeon's hand, and ophthalmological procedures on the cornea or lens. We report here on initial psychophysical tests that investigate whether the HHFM enables improved force control when users are asked to hold a small target force. (U.S. Patent Pending)

Methods: In this experiment, subjects are asked to contact a flat target with the HHFM, and match the target force level: 5 grams (49mN). Subjects are tested with and without force magnification, and in both 'push' and 'pull' directions. The magnitude and direction of the target forces, as well as the magnification state, are presented in random order. An integrated experimental platform was built for these psychophysical tests (**Figure 1**). An Analog Devices microprocessor (ADuC7026), programmed in C, controls the visual and auditory feedback presented to the subject throughout the experiment. An NI-6009 DAQ collects seven channels of 14-bit voltage data at 1000 Hz.

Figure 1. Experimental Platform for the Isometric Low Force Experiment

At the beginning of each trial, three LEDs provide a visual cue that guides the subject to a particular target force. When the subject reaches the target force, indicated by the yellow LED, they are instructed to hold that force steadily until the end of the trial (approximately six seconds in total). Visual feedback is removed two seconds before the end of each trial. A high precision load cell (Transducer Techniques GSO-100) continuously reports the force applied by the user for further statistical analysis.

Statistical Analysis: Data analysis was performed using Python, Matlab, and Excel. The effect of haptic feedback delivered by the HHFM is examined by comparing how magnification state changes the average applied force at various target levels. **Figure 2**, for example, shows force data collected at the 49mN target level in both push and pull directions, with or without force magnification.

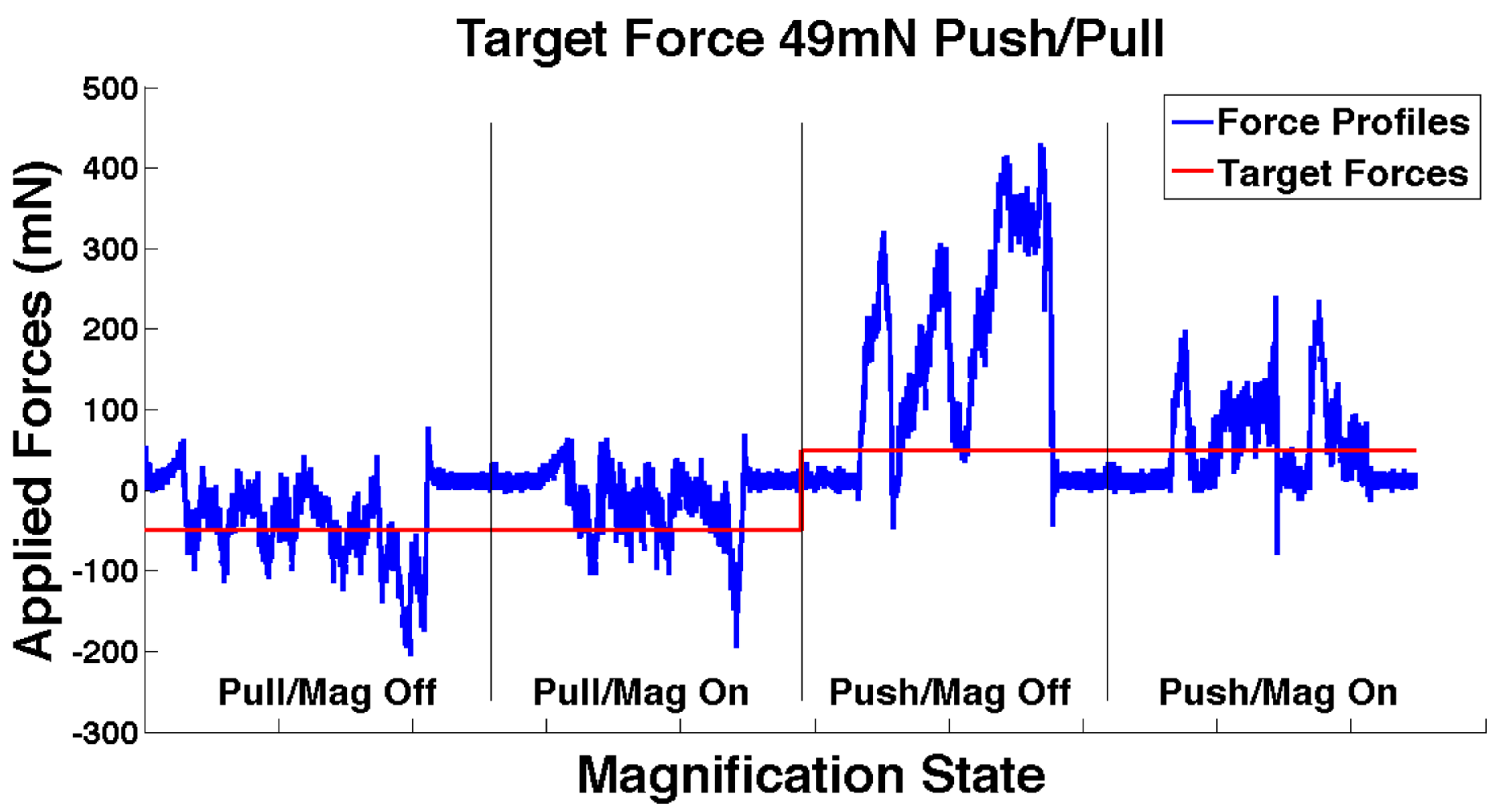

Figure 2. Recorded applied force data with target at 49mN .

Statistical Analysis (cont.): The efficacy of the HHFM to reduce variability in applied forces is also evaluated. We hypothesize that with the magnification on, the user will be able to hold small forces with less variability. We test this hypothesis by examining the standard deviations of the forces applied by the user, with force magnification turned on or off. We completed a preliminary statistical analysis of data collected at the 49mN target level. Only data after the user first reaches the target range (within plus or minus 1.5 grams, or 14.7mN, of the target force) are considered in the analysis.

Results: In **Figure 3**, we plot the average applied force against its standard deviation. We see that with magnification on, subjects are able to more precisely apply the target force, and with less variability. **Figure 3** also shows the difference in applied force with and without visual feedback, as well as for the entire experiment, for both magnification states.

Using five trials per condition as units of observation, separate ANOVAs (analysis of variance) were performed on the measures of mean within-trial force and within-trial standard deviation of applied force. Each ANOVA was a two by two with factors of force direction (push or pull) and magnifier status (on or off).

In both ANOVAs, the sole significant effect was that of magnifier status: for mean force, $F(1,4)=10.41$, $p=0.03$ and for the standard deviation of force, $F(1,4)=87.68$, $p<.001$.

Conclusions: Preliminary results indicate that the HHFM may enable users to more accurately apply small target forces and sustain such forces with less variability by augmenting the perception of tool-target interaction. Additional psychophysical experiments will be conducted with more subjects and target forces to further validate the effectiveness of the Hand Held Force Magnifier.

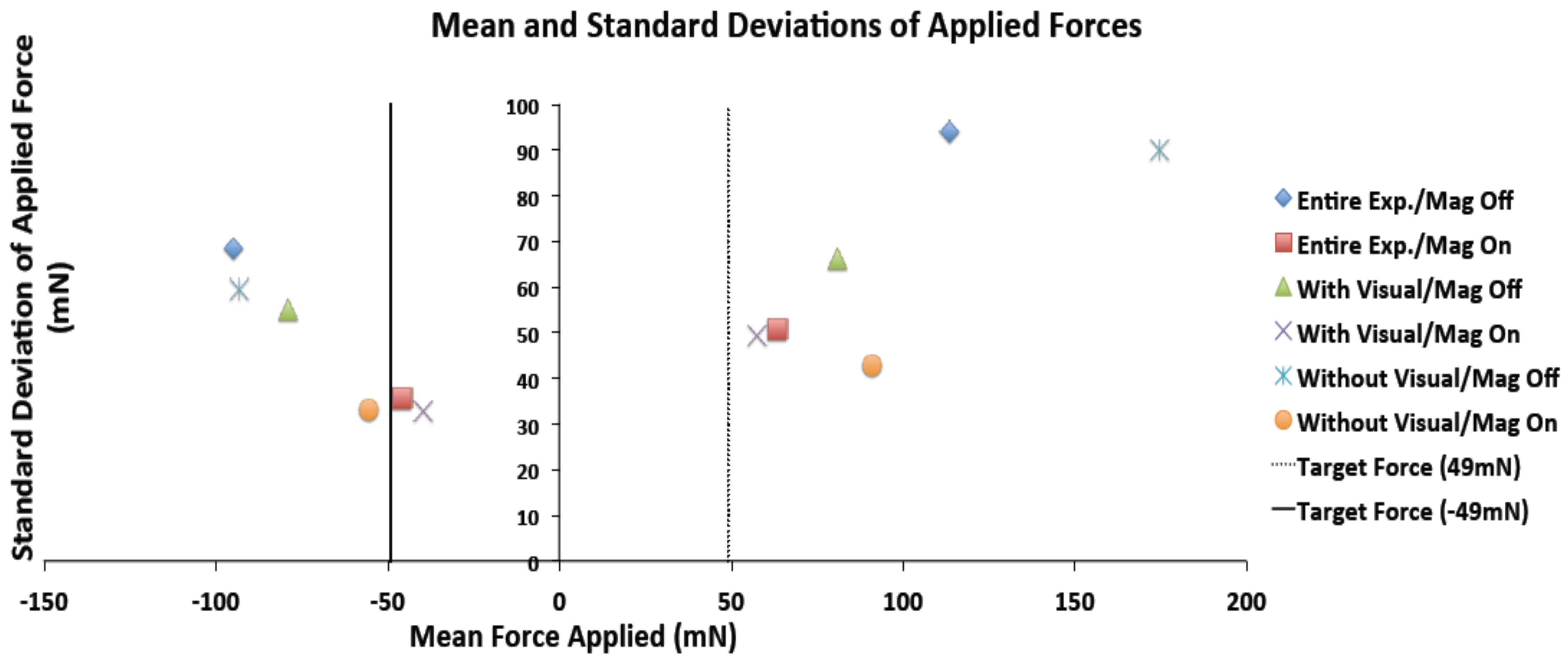

Figure 3. Mean and standard deviations of applied forces

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References:

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